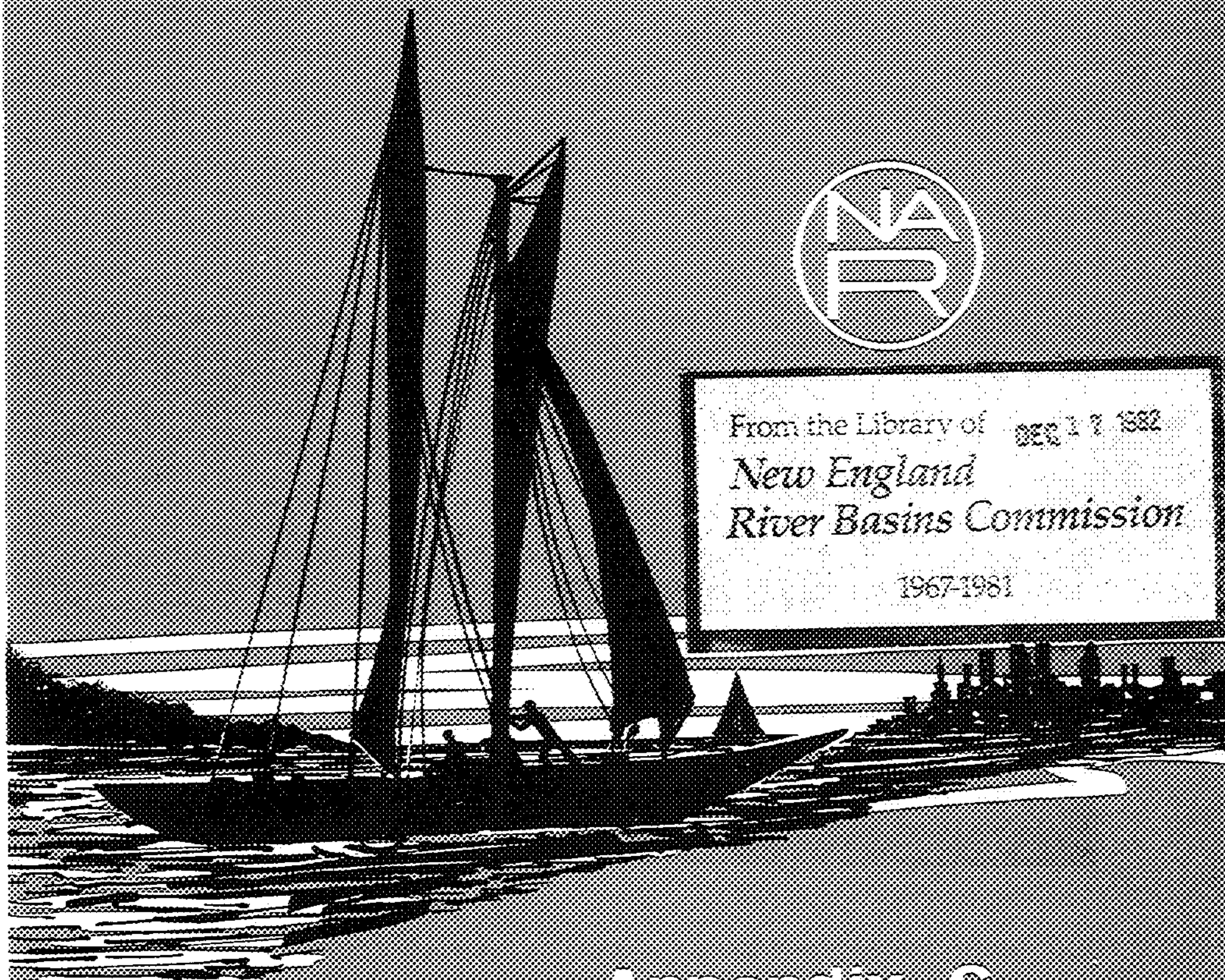
North Atlantic Regional Water Resources Study



Appendix C
Climate, Meteorology and Hydrology

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY COORDINATING COMMITTEE
MAY 1972

The North Atlantic Regional Water Resources (NAR) Study examined a wide variety of water and related land resources, needs and devices in formulating a broad, coordinated program to guide future resource development and management in the North Atlantic Region. The Study was authorized by the 1965 Water Resources Planning Act (PL 89-80) and the 1965 Flood Control Act (PL 89-298), and carried out under guidelines set by the Water Resources Council.

The recommended program and alternatives developed for the North Atlantic Region were prepared under the direction of the NAR Study Coordinating Committee, a partnership of resource planners representing some 25 Federal, regional and State agencies. The NAR Study Report presents this program and the alternatives as a framework for future action based on a planning period running through 2020, with bench mark planning years of 1980 and 2000.

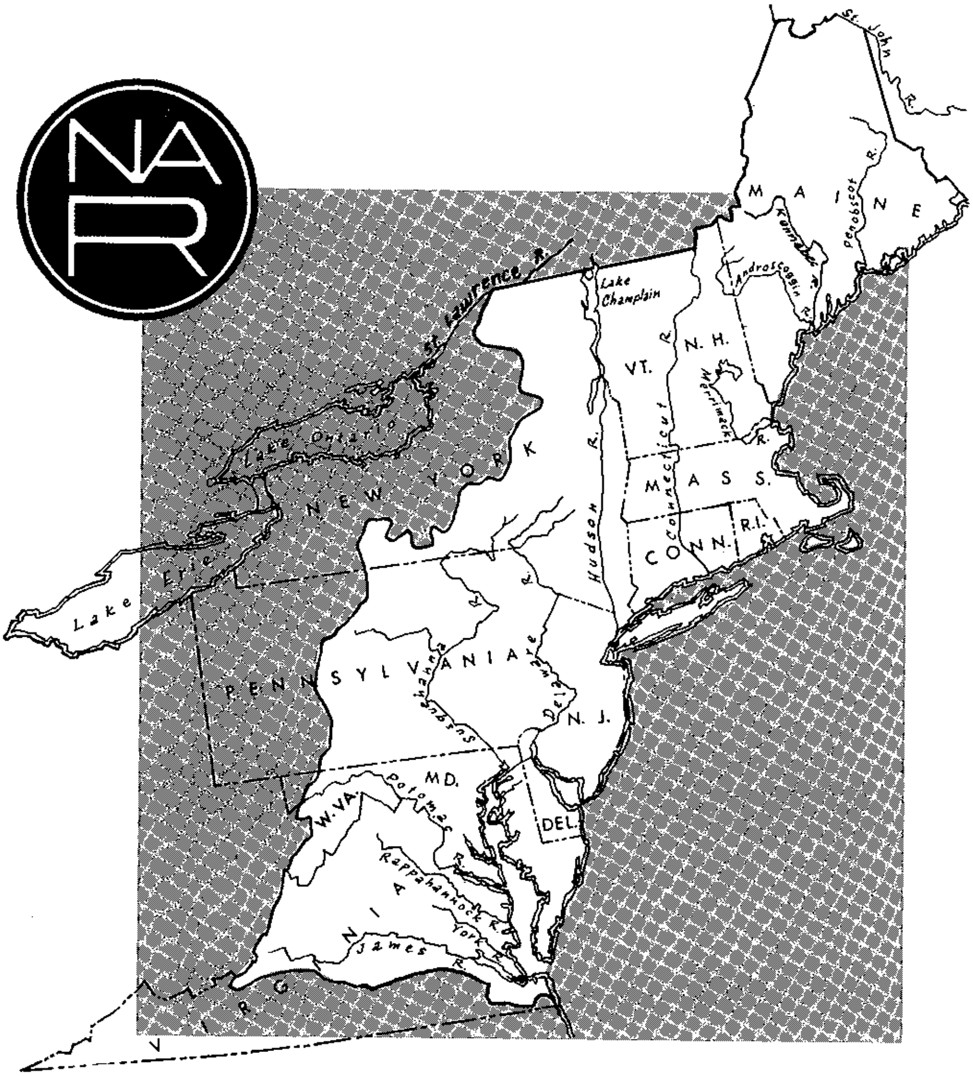
The planning partners focused on three major objectives -- National Income, Regional Development and Environmental Quality -- in developing and documenting the information which decision-makers will need for managing water and related land resources in the interest of the people of the North Atlantic Region.

In addition to the NAR Study Main Report and Annexes, there are the following 22 Appendices:

A. History of Study
B. Economic Base
C. Climate, Meteorology and Hydrology
D. Geology and Ground Water
E. Flood Damage Reduction and Water Management for Major Rivers and Coastal Areas
F. Upstream Flood Prevention and Water Management
G. Land Use and Management
H. Minerals
I. Irrigation
J. Land Drainage
K. Navigation
L. Water Quality and Pollution
M. Outdoor Recreation
N. Visual and Cultural Environment
O. Fish and Wildlife
P. Power
Q. Erosion and Sedimentation
R. Water Supply
S. Legal and Institutional Environment
T. Plan Formulation
U. Coastal and Estuarine Areas
V. Health Aspects

WATER RESOURCES NEEDS AND POTENTIALS FOR AN EXPANDING SOCIETY

Appendix C
Climate, Meteorology and Hydrology



Prepared by

North Atlantic Regional Water Resources Study Group
North Atlantic Division
Corps of Engineers, U.S. Army

for the

NORTH ATLANTIC REGIONAL WATER RESOURCES STUDY COORDINATING COMMITTEE

SYLLABUS

The North Atlantic Region, covering about 172,600 square miles from Maine to Virginia, contains wide differences in physical features and composition, and climatic, meteorologic and hydrologic characteristics.

The climate of the Region is humid, with four distinct seasons, and is characterized by frequent weather changes. The average annual temperature varies from slightly less than 40° F. in northern New England to about 60° F. in southern Virginia. Average annual precipitation is about 41 inches, fairly evenly distributed throughout the year.

A great variation in weather occurs in the Region. The more extreme meteorologic phenomena are responsible for relatively frequent localized flash flooding, the occasional widespread floods covering one or more large river basins, and the infrequent prolonged droughts affecting large portions of the Region.

Floods occur as a result of heavy rains, with or without snowmelt, and are related to thunderstorms, transcontinental disturbances and hurricanes and coastal storms. Storms resulting in extreme flows have occasionally occurred within relatively short time intervals. Examples are the hurricanes of August 1955 in the New England and Hudson-Delaware areas and the storms of March 1936, which affected large parts of the Region.

Low flows occur on a yearly cyclical basis and generally have a duration of three or four months in late summer and early fall. Occasionally, a prolonged period of low flow extending beyond seasonal limits occurs and may last for several years. During the drought of the 1960s, many gaging stations recorded annual flows for several consecutive years that were on the order of 50% or less of the long-term average.

The long-term average flow in the North Atlantic Region, including flow from contributing drainage area in Canada is about 260,000 c.f.s., which is equivalent to runoff of about 1.5 c.f.s. per square mile. Average runoff varies from as much as 2.5 c.f.s. per square mile at a few stations in New England and New York, to less than 1 c.f.s. per square mile at stations in the Potomac, York and Rappahannock River Basins.

A Regional analysis of minimum flows was accomplished in connection with the determination of existing firm resource for plan formulation and supply model studies. These flows, based on shortage index criteria, are approximately equivalent to seven-day average flows having 50-year recurrence intervals. On a Sub-regional basis, they vary from .06 c.f.s. per square mile for southernmost Sub-region F, to .31 c.f.s. per square mile for Sub-region A, in Maine.

Other Regional analyses include the generation of synthetic monthly streamflows at key stations throughout the Region, the determination of yield-storage relationships for both major river and upstream areas and studies of flood control impoundment effects on major rivers.

Separate summaries are included in the Appendix for each of the six NAR Sub-regions. These summaries contain more detailed meteorologic and hydrologic descriptions and data as well as results of certain of the analyses.

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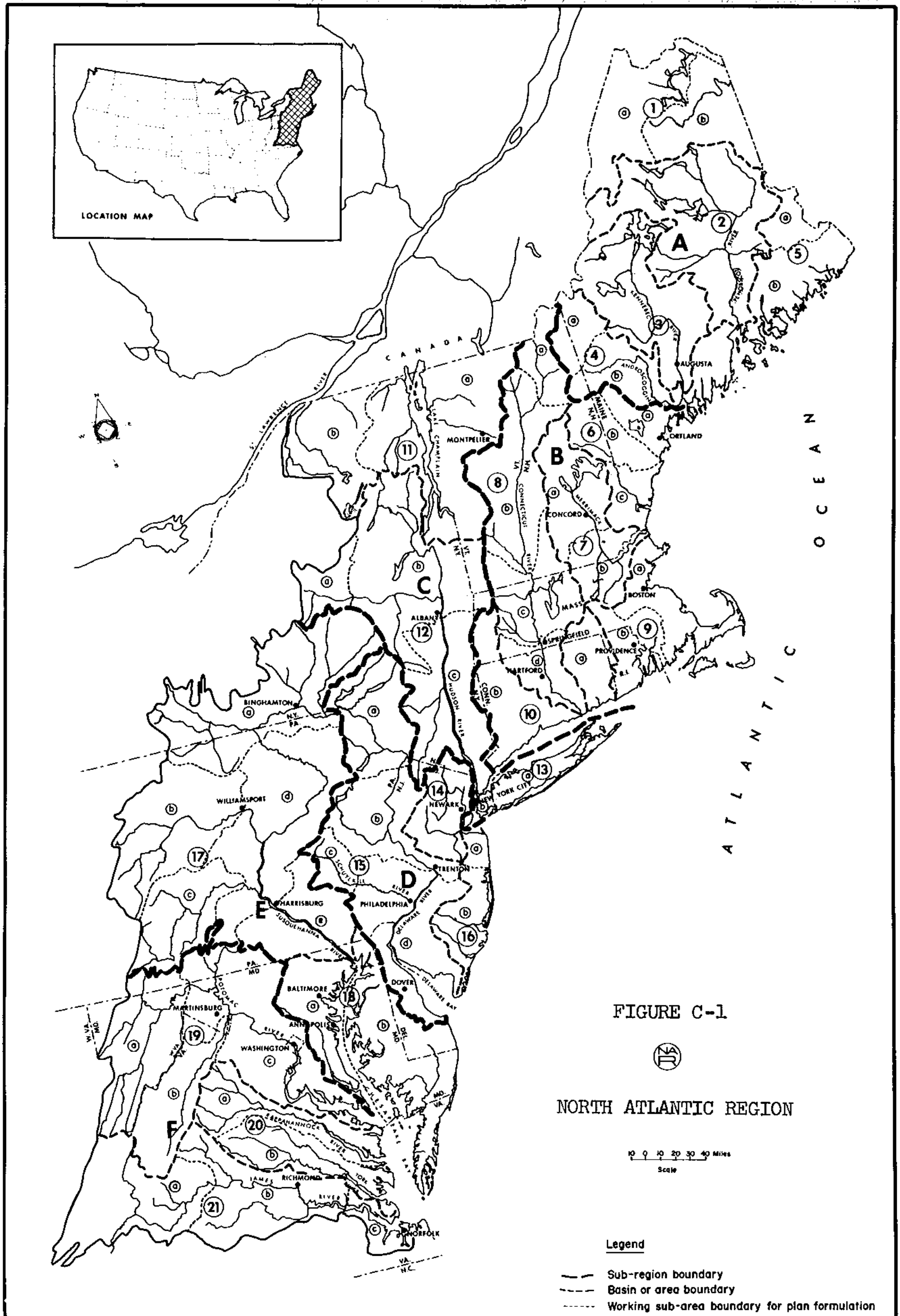


FIGURE C-1

NORTH ATLANTIC REGION

CHAPTER 1. INTRODUCTION

PURPOSE AND SCOPE

PURPOSE

The purpose of this Appendix is to describe the Region from a climatic, meteorologic and hydrologic viewpoint, and to provide hydrologic data, analyses and techniques necessary for the consideration of surface water problems and an evaluation of alternative solutions proposed for these and related problems. The analyses contained herein are consistent with the broad-scaled objectives of a framework water resources planning study.

SCOPE

Appendix C includes descriptions of the North Atlantic Region's climatic and hydrologic environments and summaries of selected available data. Information is presented on existing surface water quantity, quality and suitability, and on floods, droughts and existing regulation. Related aspects such as ground water and estuaries and coastal areas are also considered.

Analyses contained in this Appendix include computer procedures for the simulation of streamflow and the development of yield-storage information for major rivers and upstream watersheds. Studies of minimum flow and generalized techniques for evaluating the effects of flood control impoundments are also included. All methods, the input data used and the results obtained were tailored to the need of a framework study. Thus methods used and results obtained are useful as general guides and are not substitutes for detailed basin or project hydrologic studies.

Data in Appendix C were taken primarily from publications of other Federal agencies, completed river basin study reports, and other NAR Study Appendices. Streamflow generation studies were accomplished through the use of a computer program developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center, and implemented with the assistance of personnel from the Center. The Hydrologic Engineering Center accomplished the analysis of flood control impoundment effects using basic data provided by the North Atlantic Division, U.S. Army Corps of Engineers. The U.S. Department of Agriculture provided the analysis of yield from upstream storage.

STUDY RELATIONSHIP

All parts of the NAR Study report are concerned with water and related land resources and, therefore, related in some degree to Appendix C. This Appendix is most directly related to Appendix D, Geology and Ground Water, which contains analyses of the ground water aspects of the available resource; and Appendix E, Flood Damage Reduction and Water Management for Major Rivers and Coastal Areas. Appendix E integrates water availability data developed in Appendices D and C, as well as that developed in Appendix F, Upstream Flood Prevention and Water Management.

The yield and minimum flow analyses in Appendix C are essential elements in the derivation of input data on the existing and the practically developable resource for use in the NAR Supply Model. Supply model studies of prospective resource development and allocation are covered in Appendix T, Plan Formulation.

CHAPTER 2. REGIONAL DESCRIPTION

The North Atlantic Region covers an area of about 172,600 square miles, stretching some 200 miles from Maine to Virginia along the Atlantic Seaboard, and including the District of Columbia, all the New England States, the states of New Jersey and Delaware, and parts of New York, Pennsylvania, Maryland, Virginia and West Virginia, as shown in Figure C-1. The Region encompasses all river basins, coastal embayments and estuarine waters draining into the Atlantic Ocean north of the Virginia-North Carolina border, and St. Lawrence River drainage east of the international boundary.

TOPOGRAPHY

The Region is represented by a wide spectrum of physical features and natural composition as a result of its vast extent and marked differences in its geologic history. Most of the terrain is mountainous or hilly upland, with about 15% of the lowlands situated in the Coastal Plain. Altitudes rise to more than 6,000 feet above mean sea level.

The Region's major features are the results of (1) compression and up lifting of the Earth's crust which formed the Appalachian Mountain Range; (2) glacial erosion and deposition as far south as Pennsylvania, which has left coverings of till in upland areas and stratified drift in lowlands; and (3) accumulation of materials eroded from these and other uplifted rocks forming a seaward thickening wedge of generally unconsolidated sedimentary rocks known as the Coastal Plain.

Northern New England has the most rugged terrain with substantial relief except in the low, gently rolling coastal lowlands in New Hampshire and southeastern Maine. The highest elevation in the NAR is 6,288-foot Mount Washington in New Hampshire. There are the Adirondacks of New York State and the Green Mountains of Vermont, separated by the Champlain Valley, and the St. Lawrence Valley to the north. Southern New England is generally rolling uplands, bisected by the Connecticut River Valley, a broad lowland ranging from 5 to 15 miles wide. Cape Cod and the Rhode Island and Connecticut shorelines are lowlands.

Most of southern and western upstate New York is in the Appalachian Plateau, lowering to the Champlain and Hudson Valleys to the east. Southernmost upstate New York physically resembles New England's upland areas. The Appalachian Highlands cover most of interior Pennsylvania, extending into New Jersey, where there is a fairly sharp division between these highlands and the Atlantic Coastal Plain at the Fall Line, which is a meeting point of relatively elevated uplands and low sloping plains, characterized by a fairly abrupt steepening of stream gradients.

The Coast Plain extends southward from Cape Cod through Long Island, the southern three-fifths of New Jersey and all of Delaware, to eastern Maryland and Virginia. Its western boundary is the Fall Line, which usually marks the head of navigation on principal streams. Some of the NAR's larger metropolitan centers are located along this demarcation, including New York, Philadelphia, Baltimore and the District of Columbia.

The Piedmont, Blue Ridge and Appalachian Plateaus are located in the southern part of the Region west of the Coastal Plain. These plateaus cover the western half of Maryland, the western portion of Virginia, and the NAR portion of West Virginia.

CLIMATE AND METEOROLOGY

The North Atlantic Region is located between 37° and 47° North Latitude, and lies in the global zone of westerly winds in the mean path of tropical air masses from the Gulf of Mexico. The Appalachian Mountains to the west and the Atlantic Ocean to the east have a significant influence on the Region's climate. The interaction between northward moving warm air masses from the Gulf and eastward progressing continental air masses is conducive to the development of rapid climatic changes and major storms. Precipitation is generally plentiful throughout the Region.

CLIMATE

The overall climate of the Region is humid, with four distinct seasons, and is characterized by frequent weather changes. Along the coast, the climate is moderated substantially by the effects of the ocean and large bays, in contrast to inland portions, particularly the mountain ranges, where more marked extremes in temperature and precipitation occur.

During the winter, onshore winds tend to maintain higher temperatures in coastal areas, because the ocean retains heat longer than the land mass. Conversely, summers are cooler along the coast because of the slower rate of heat absorption by the Atlantic Ocean.

Winds are deflected and guided by ridges and valleys which have a general north-to-south orientation. Extreme variations in low temperatures, snowfall, frost penetration and length of growing season, are the result of this general north-south movement, as well as factors such as latitude, altitude and proximity to the coast.

METEOROLOGIC DATA

Observations of climatological data from numerous stations of the National Weather Service of the National Oceanic and Atmospheric Administration, U.S. Department of Commerce (formerly the U.S. Weather Bureau), over a period of many years have been used to characterize the Region's weather. These data were also used in the preparation of maps showing lines of equal annual temperature, precipitation and snowfall. More than 140 recording stations were used for the temperature map, 220 for the precipitation map, and about 130 for the snowfall map. Many of the locations are equipped to record at least two and, in many cases, all three of these parameters. More specific information is included in the Sub-regional Summaries.

Temperature

The average annual temperature in the NAR varies from slightly less than 40° F. in northern New England to about 60° F. in southern Virginia. Northern winters are fairly long and severe, with growing seasons averaging less than 100 days in some areas. In the southern portion of the Region, growing seasons average up to 200 frost-free days, and the summers are long and hot. The Atlantic Coastal influence on temperature is greatest in the fall, delaying the first killing frost. This results in a coastal frost-free season averaging from 20 to 40 days longer than in areas a short distance inland. Figure C-2 shows isotherms of average annual temperature in the NAR.

Precipitation

Average annual precipitation in the Region is about 41 inches, distributed fairly evenly throughout the year, and ranging from slightly less than 30 inches near the northern end of Lake Champlain in New York and Vermont, to more than 70 inches in some mountainous areas in Maine and New Hampshire. Precipitation is generally about four inches greater along the coast than in nearby inland areas. Most of this difference is accounted for by the greater coastal precipitation in the fall, since most of the coast receives less precipitation in spring and winter. There is little difference in the summer. Figure C-3 is an isohyetal map showing equal average annual precipitation in the NAR.

Wide fluctuations in precipitation from the average occur frequently, resulting in extreme high or low streamflows in parts of the Region. Periods of precipitation deficiency occasionally last for months or even years, as in the case of the droughts of the 1930s and the 1960s, and affect large portions of the NAR.

Average annual snowfall is predominantly a function of latitude, although some high altitude areas in the south receive much more snow than more northerly coastal lowlands. Snowfall in the extreme southern coastal portion averages about five inches, while more than 100 inches

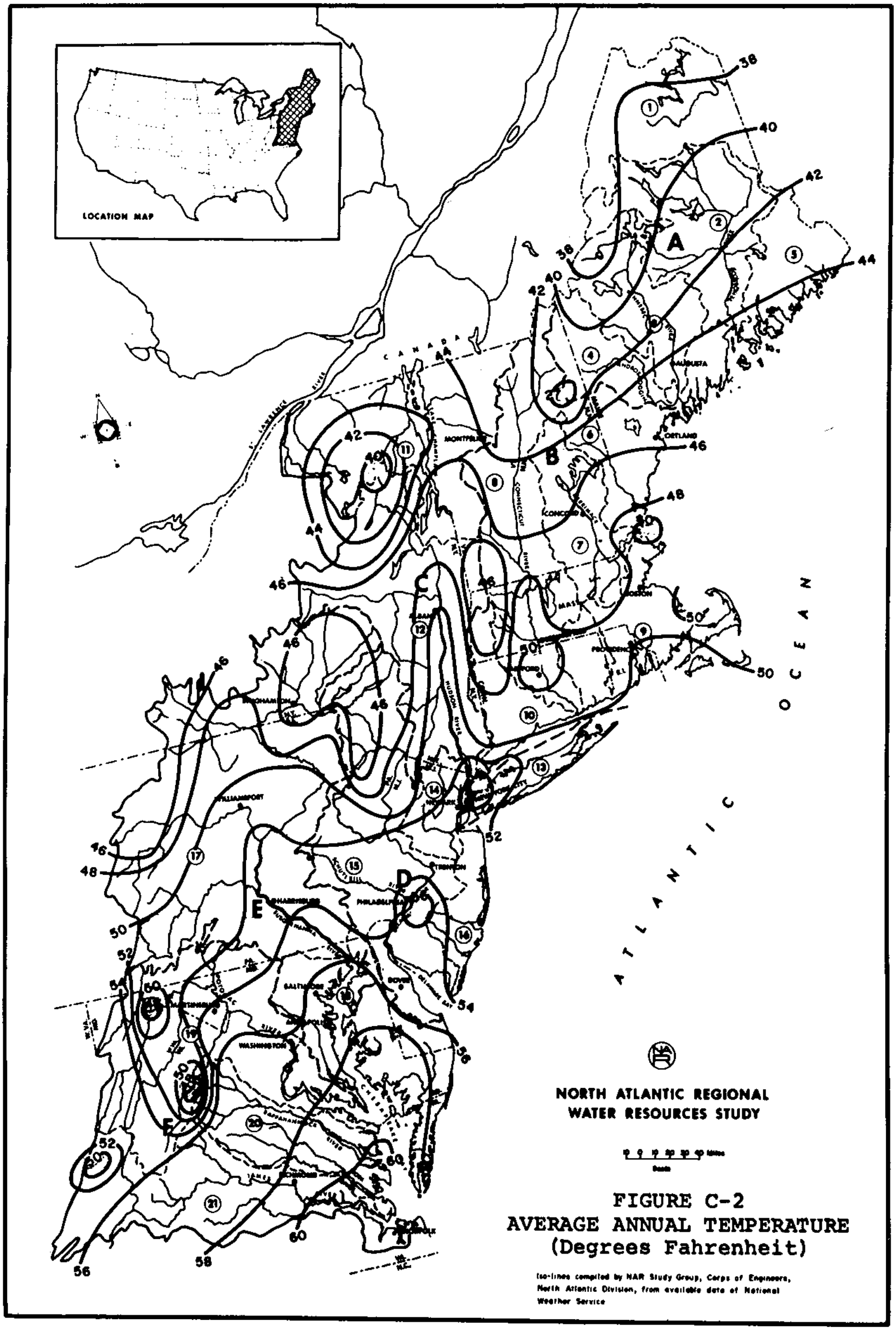


FIGURE C-2
AVERAGE ANNUAL TEMPERATURE
(Degrees Fahrenheit)

Iso-lines compiled by NAR Study Group, Corps of Engineers, North Atlantic Division, from available data of National Weather Service

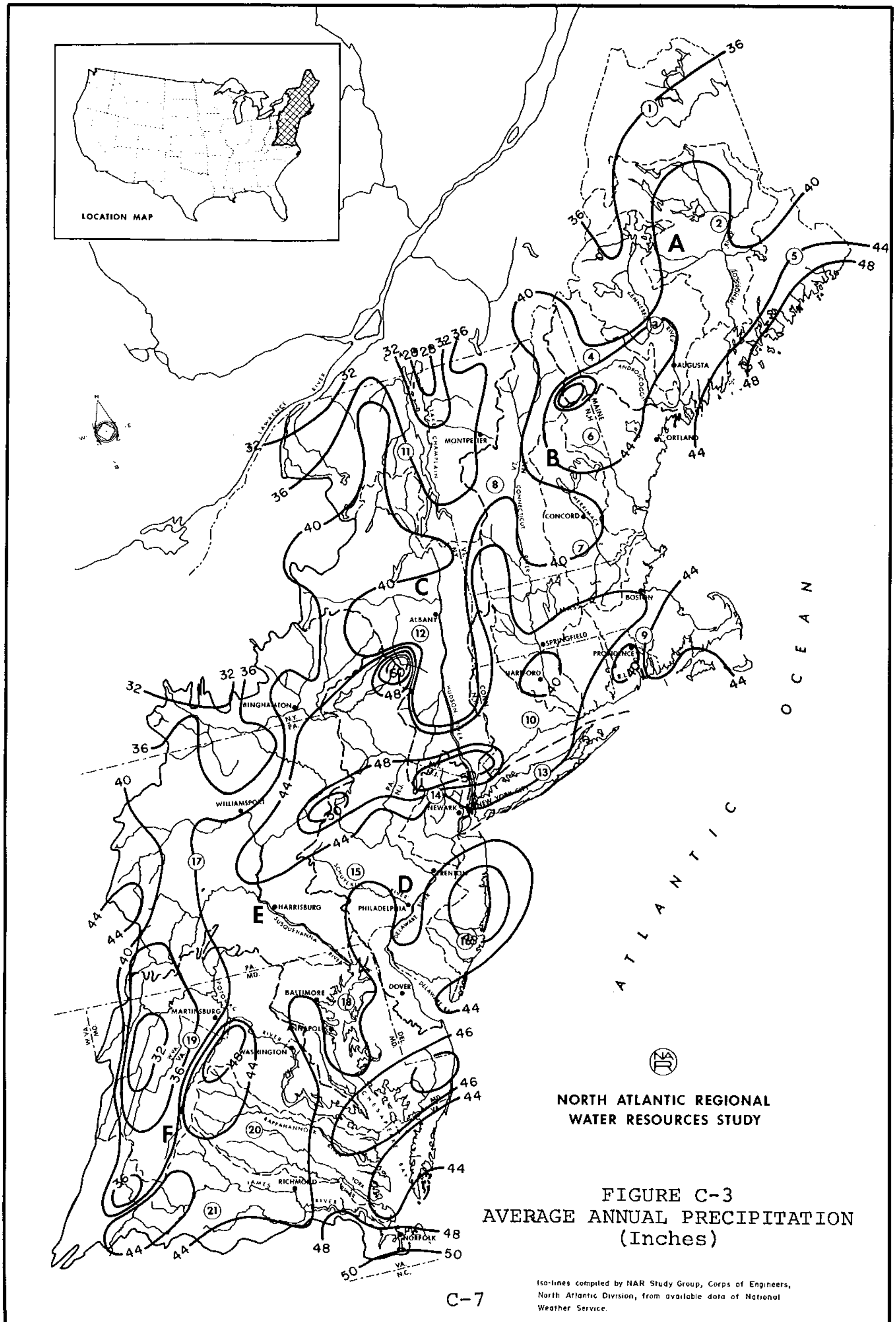


FIGURE C-3
AVERAGE ANNUAL PRECIPITATION
(Inches)

Iso-lines compiled by NAR Study Group, Corps of Engineers, North Atlantic Division, from available data of National Weather Service.

falls in northern Maine and northern New York State. Lines of equal average annual snowfall are shown on Figure C-4.

Humidity

Relative humidity is the amount of moisture in the air relative to the amount which would saturate the air at given temperature and pressure. Since the amount of moisture necessary to saturate the air is greater at higher temperatures, relative humidity may be misleading as to the quantity of moisture present. For example, a relative humidity of 50% at 90° F. indicates more moisture content than a relative humidity of 60% at 70° F. The wet bulb temperature, which is the temperature of a moist, ventilated, shaded thermometer bulb, is the point of equilibrium between air warmth and the evaporational cooling effect of the moist glass surface of the bulb. Absolute humidity is generally higher at higher wet bulb temperatures (in the above example, the wet bulb readings would be about 75° F. and 60° F., respectively), and can be used more conveniently to indicate comfort or discomfort. An empirical difference exists between the wet bulb temperature and dew point temperature. Dew point temperature is the temperature at which saturation would occur for any actual water content present, if the air were cooled at constant pressure.

Mean relative humidity generally averages about 80% along the coast, and about 70% in inland areas during the summer and early fall, and about 70% during the winter throughout the NAR.

Dew point temperatures range from about 10° F. in Maine to 30° F. in Virginia in January, and in July, from 55° F. in Maine to 65° F. in Virginia.

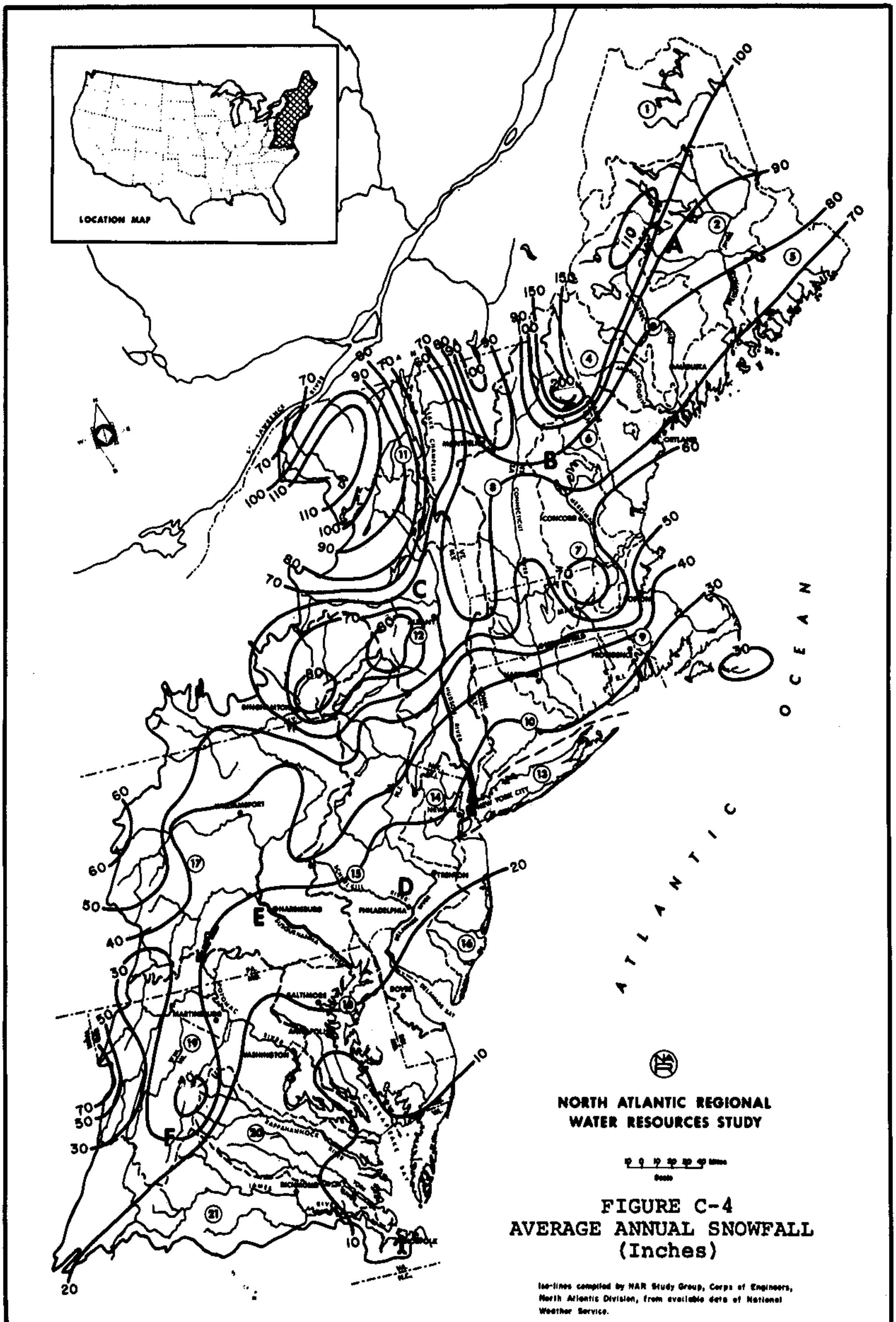
Differences in relative humidity at Caribou, Me., and at Norfolk, Va., are minimal. Average annual relative humidities, measured at 1 a.m., 7 a.m., 1 p.m. and 7 p.m., are 82%, 79%, 62% and 73%, respectively, at Caribou, and 81%, 79%, 58% and 72%, respectively, at Norfolk. However, the average annual dew point temperature is 31° F. at Caribou, and 49° F. at Norfolk.

Additional data on humidity and dew point temperature are presented in the Sub-regional Summaries. The values are taken from charts included in the "Climatic Atlas of the United States," published by the Environmental Data Service in June 1968.

Evaporation

Total evaporation, termed evapotranspiration, includes all losses to the atmosphere from land and water sources, including transpiration is the process by which water absorbed through plant roots is evaporated from leaf surfaces.

Evaporation rates depend on a number of factors including temperature, atmospheric pressure, wind, the quality of water, and the nature of the


LOCATION MAP
NORTH ATLANTIC REGIONAL
WATER RESOURCES STUDY
FIGURE C-4
AVERAGE ANNUAL SNOWFALL
(Inches)
ATLANTIC OCEAN
Iso-lines compiled by NAR Study Group, Corps of Engineers, North Atlantic Division, from available data of National Weather Service.

evaporating surface. Evaporation tends to decrease with increasing elevation, due in part to the decrease in atmospheric and dew point temperatures.

Annual evapotranspiration varies from about 15 to 30 inches in the NAR, generally increasing from north to south. If it is assumed that recharge of, and withdrawal from, ground water are in balance in a basin, the average evapotranspiration would be approximately equivalent to the difference between average annual precipitation and average annual runoff.

Mean annual lake evaporation varies from 20 inches in northern Maine to slightly more than 40 inches in southeastern Virginia. Most of this evaporation, about 70% in Virginia and more than 80% iin Maine, occurs from May to October.

HYDROLOGY

The long-term average streamflow in the North Atlantic Region, including the contributing drainage area in Canada, is about 260,000 cubic feet per second (c.f.s.), or 1.5 cubic feet per second per square mile (c.s.m.). However, variations are wide, both in time and place. This section covers some of the mean and extremed extreme flow patterns, highlighting the variations within the NAR with selected hydrologic data. Material on existing storage, and a brief summary of ground water suitability and the relationship between ground water and surface water are also included.

HYDROLOGIC DATA

Streamflow originating in the Region, including the portions of the St. John, St. Croix and Connecticut Rivers which receive flow from Canada, is measured at some 950 continuous recording gages maintained by the U.S. Geological Survey at locations throughout the NAR.

However, portions of the streamflow are not gaged. One reason for this is the tidal influence where net fresh water outflow is underlain by ocean water, such as in the Hudson River south of Green Island, or in the Delaware River just south of Trenton. Where areas are ungaged, nearby gaged areas with similar topographic, geologic and meteorologic features must be relied on for estimating outflow.

Basic data from available information, obtained mainly from U.S. Geological Survey Water-Supply Papers, are presented in tables in the Sub-regional Summaries. These tables show station drainage areas, number of years of observation, average and extreme flow data, and structures affecting natural runoff above each selected station.

Drainage Areas

The Region was divided into 21 large hydrologic Areas for purposes of analysis. These drainage areas, shown on Table C-1, were based primarily on the land and water areas developed in the preparation of Appendix G, Land Use and Management. These land and water Areas were adjusted to conform as much as possible with information in several sources, including the U.S. Department of Agriculture's 1958 Conservation Needs Inventory, the 1967 Statistical Abstract of the U.S. Department of Commerce, the study of land and water resources of the New England-New York Region (NENYIAC), drainage area information on gaged areas available through the Interior Department's U.S. Geological Survey, and completed individual river basin studies.

Adopted drainage areas (Table C-1, p. 12) agree closely with available basin and State area data published elsewhere. However, it was impossible to reconcile all of the various sources of information without some variation. For example, while the drainage area for Area 7, Merrimack River Basin, is shown as 5,050 square miles, U.S. Geological Survey data indicates a drainage area of 5,010 square miles. This difference is the largest known to exist in the 21 NAR Areas. For the political areas, a difference is noted for the District of Columbia. Whereas the 1967 Statistical Abstract gives an area of 67 square miles, the Potomac River Basin Report (Baltimore District, U.S. Army Corps of Engineers, February 1963) indicates 69 square miles. The latter figure was adopted for use in the NAR Study for consistency with the referenced report. A recent detailed analysis by the State of Pennsylvania in coordination with the U.S.G.S. resulted in State totals of 6,466, 21,035 and 1,584 square miles in the Delaware, Susquehanna and Potomac Rivers respectively. These figures were not used in the analyses presented in this Appendix.

Average Flows

Average streamflow for the Region, including the flow from about 4,835 square miles in Canada, totals about 260,000 c.f.s., the equivalent of almost 20 inches of runoff for the entire 177,421-square-mile drainage area. This runoff, from only 5% of the total drainage area of the United States, represents some 9% of the Nation's total average runoff of 1,794 billion gallons per day (b.g.d.), as estimated in "The Nation's Water Resources," the 1968 National Assessment of the Federal Water Resources Council.

Runoff in the NAR exhibits relatively low annual variability in comparison with the rest of the country. According to the 1968 National Assessment, in 19 out of 20 years, on an average, annual runoff will be equal to about 69% of the mean. This is higher than in any of the other water resources regions designated by the Water Resources Council. In other words, the annual flow in 95% of the years will equal or exceed 69% of the long-term average. Within the NAR, the variability is greatest in Sub-region F, with only about 55% of the average flow exceeded in 95% of the years. The variability is lowest in Sub-region C, where about 70% of the average flow is exceeded in 95% of the years.

Runoff averages nearly 1.5 c.s.m. for the entire Region, with

TABLE C-1
DRAINAGE AREAS
(Square miles)

	Me.	N. H.	Mass.	Conn.	Vt.	R.I.	N. Y.	N. J.	Pa.	Del.	Md.	Va.	D.C.	W.Va.	NAR	Canada	TOTAL	
Area 1	7,359														7,359	4,096	11,455	Area 1
Area 2	8,525														8,525		8,525	Area 2
Area 3	5,870														5,870		5,870	Area 3
Area 4	2,730	720													3,450		3,450	Area 4
Area 5	6,231														6,231	625	6,856	Area 5
Area 6	2,499	1,696	13												4,208		4,208	Area 6
Area 7		3,841	1,209												5,050		5,050	Area 7
Area 8		3,046	2,726	1,436	3,298										11,136	114	11,250	Area 8
Area 9			3,367	57		1,152									4,576		4,576	Area 9
Area 10			751	3,478		61	265								4,555		4,555	Area 10
Area 11					5,230		6,670								11,900		11,900	Area 11
Area 12			190	36	450		12,435	255							13,366		13,366	Area 12
Area 13							1,901								1,901		1,901	Area 13
Area 14							157	2,219							2,376		2,376	Area 14
Area 15							2,362	2,969	6,422	1,004	8				12,765		12,765	Area 15
Area 16								2,393							2,393		2,393	Area 16
Area 17							6,309		20,927		274				27,510		27,510	Area 17
Area 18									75	1,053	6,058	959			8,145		8,145	Area 18
Area 19									1,570		3,818	5,723	69	3,490	14,670		14,670	Area 19
Area 20												6,000			6,000		6,000	Area 20
Area 21												10,555		45	10,600		10,600	Area 21
TOTAL	33,214	9,303	8,256	5,007	9,608	1,213	30,099	7,836	28,994	2,057	10,158	23,237	69	3,535	172,586	4,835	177,421	TOTAL

about 1.7 c.s.m. in New England, 1.5 c.s.m. in the Hudson and Delaware Rivers and rivers draining into the St. Lawrence River, and 1.3 c.s.m. to 1 c.s.m., north-to-south, for Chesapeake Bay drainage. Table C-2 gives estimated runoff for the 21 Areas. Estimates were based, for the most part, on observed streamflow. Figures given for Long Island (Area 13) include an estimate of sub-surface outflow of ground water because it accounts for such a large portion of the total outflow. Ground water also supplies most of the surface flow to the small streams on Long Island.

TABLE C-2
AVERAGE RUNOFF

	CUBIC FEET PER SECOND	INCHES PER YEAR		CUBIC FEET PER SECOND	INCHES PER YEAR
Area 1	18,740	22.2	Area 13	2,950	21.1
Area 2	14,930	23.8	Area 14	3,990	22.8
Area 3	10,060	23.3	Area 15	20,420	21.7
Area 4	6,160	24.3	Area 16	3,790	21.5
Area 5	11,650	23.1	Area 17	38,500	19.0
Area 6	7,140	23.0	Area 18	8,510	14.3
Area 7	8,330	22.4	Area 19	13,880	12.8
Area 8	18,920	22.8	Area 20	5,690	12.9
Area 9	8,170	24.2	Area 21	11,520	14.7
Area 10	7,530	22.5			
Area 11	18,790	21.4			
Area 12	20,400	20.7	TOTAL NAR	260,070	19.9

Figure C-5 shows lines of equal average annual runoff in the NAR, based on "Annual Runoff in the Conterminous United States," by Mark W. Busby (U.S. Geological Survey Hydrologic Investigations Atlas HA-212).

Floods

Peak discharge data for various gaging stations are given in the Sub-regional Summaries. This information includes discharge and stage data for the three highest occurences at each station, and maximum volumes for 1-, 6- and 54-month durations.

Flooding occurs annually in the Region, to a greater or lesser extent, as the result of heavy rains, with or without snowmelt, and hurricanes or coastal storms. Storms resulting in extreme flows have occasionally occurred within relatively short time intervals. Examples are the hurricanes of August 1955 in the New England and the Hudson-Delaware Basins areas, and the extremely intense storms of March 1936 which affected most of the NAR.

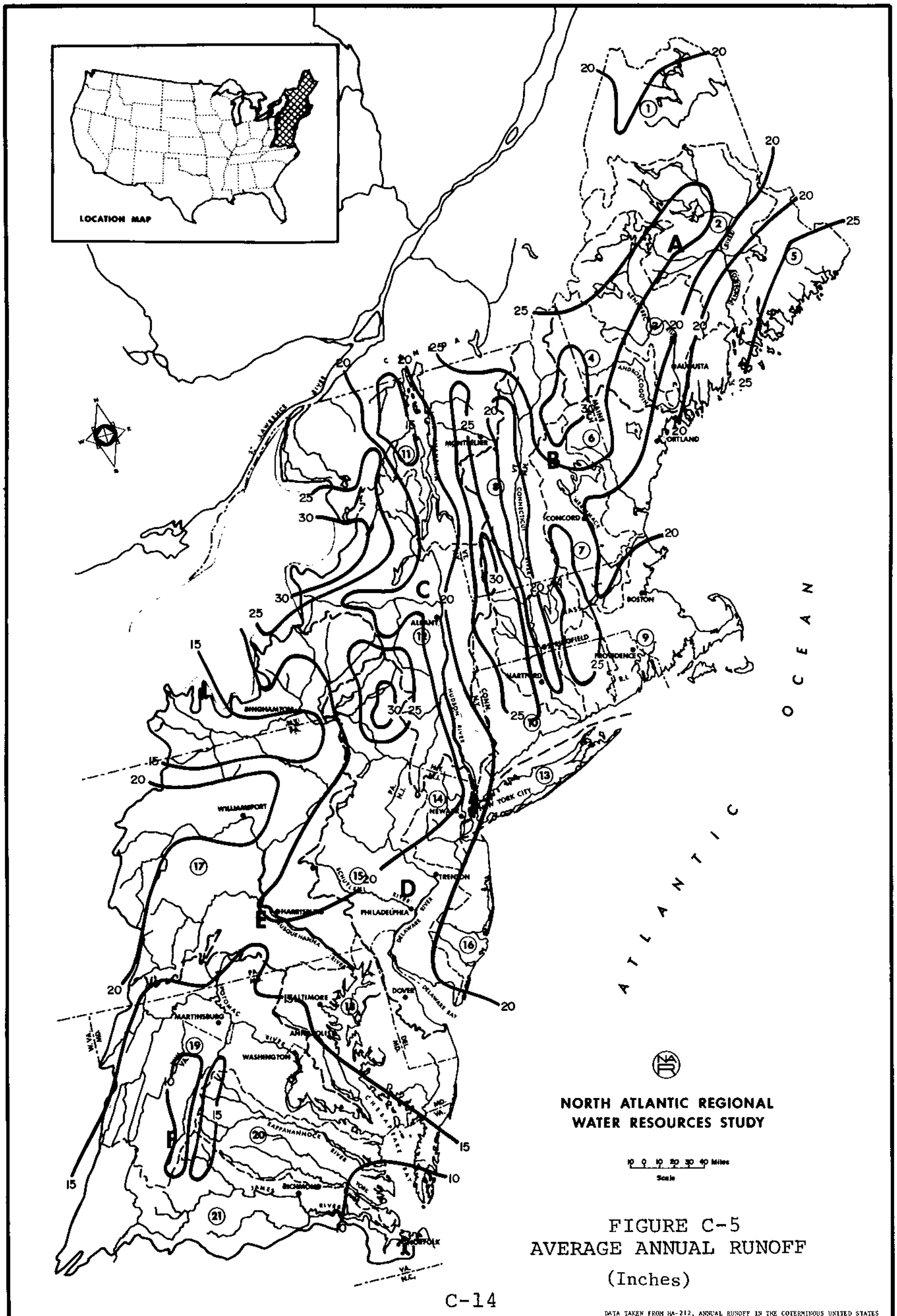


FIGURE C-5
AVERAGE ANNUAL RUNOFF
(Inches)

DATA TAKEN FROM HA-212, ANNUAL RUNOFF IN THE COTERMINOUS UNITED STATES BY MARK W. BUSBY, PUBLISHED BY THE UNITED STATES GEOLOGICAL SURVEY.

Flooding in northern New England occurs fairly often on the smaller streams and tributaries, usually as a result of spring rains coupled with snowmelt, and sometimes worsened by the formation of ice jams. Flooding on main streams occurs less frequently because of natural and man made regulation from the many lakes and ponds. Localized storms rarely occur, but can cause destructive flooding on brooks and small streams, as in August 1939 at Baldwin, Me., where up to 12 inches of rain fell in about three hours.

Flooding in central and southern New England usually occurs in the spring when rain combines with snowmelt. However, this sector is subject to flooding at any time of the year, particularly along the coast. Occasionally, an isolated storm may be followed by a tropically-formed hurricane, producing severe flooding on a wide-scale basis, such as occurred in September 1938. Localized storms of the cloudburst type occur frequently here and cause serious flooding on brooks and streams. When hurricane waves and tides combine with gravitational high tide along the sourthern coast, severe tidal flooding occurs.

High flows in the areas draining into Lake Champlain and the St. Lawrence River occur almost every spring from snowmelt and rainfall and are often increased by ice jams. Localized flooding from summer storms and cloudbursts causes most of the damage. Generally, storms cover only a part of the area, and when a widespread storm does occur, it evidences significant variation in intensity.

Spring flooding occurs in the Hudson River Basin every few years and can be very severe at times. Continental or tropical storms can occasionally cover large areas, but most storms result in flooding only in parts of the basin. Local flash flooding in the summer is caused by thunderstorms and generally affects the small tributaries.

Norther New Jersey streams have had fairly frequent and severe flooding from summer storms, hurricanes and continental storms. Some natural detention is provided by undeveloped lowlands, but narrow, constricted channels downstream and generally flat slopes result in considerable channel overflow. The New Jersey shoreline is subject to severe tidal flooding with damages resulting from inundation, wind, and storm-driven waves.

The Delaware River Basin experiences large floods from heavy rains and spring thaws which can affect extensive areas. Tropical hurricanes, northeasters, and localized thunderstorms have all resulted in record flows and significant flooding.

Heavy early spring rains cause frequent flooding in the Susquehanna River Basin. Local flooding may occur as a result of summer thunderstorms, such as occurred in July 1935 in many of the northern tributaries. Tropical storms occasionally produce widespread flooding, although not as frequently as in other parts of the NAR.

Floods on the Potomac River and its tributaries can be produced by continental or tropical storms, thunderstorms, and combinations of these types, such as the hurricane and accompanying thunderstorm activity of October 1942. Hurricane Camille, which occurred in August 1969, affected parts of the Potomac Basin, and most of the York, Rappahannock and James River Basins. Camille can be called a meteorologic anomaly, as evidenced by the 27 to 28 inches of rainfall which fell on Nelson County, Va., in about eight hours. Maximum discharges of record were exceeded at 27 gaging stations.

Peak flows on the lower main stems of the larger rivers have caused flows of 40 c.s.m. or more on occasion, generally as a result of major Regional storms. During the widespread flooding which followed the storms of March 1936, the flow in the Androscoggin River near Auburn, Me., reached 135,000 c.f.s. (41.4 c.s.m.), and the flow in the Potomac River near Washington, D.C., was 484,000 c.f.s. (41.9 c.s.m.). In October 1942, the Potomac River flow at Washington, D.C., was almost as great, 447,000 c.f.s. (38.7 c.s.m.). As a result of Hurricanes Connie and Diane, in August 1955, the Delaware River flow at Trenton, N.J., was 329,000 c.f.s. (48.5 c.s.m.).

As drainage area decreases upstream on tributaries and smaller streams, record peak flows per square mile tend to increase sharply. Values of 20 or more times the c.s.m. in the preceding paragraph would not be unlikely where local storms over watersheds of a few square miles are considered.

The general magnitude of flood peaks of selected frequencies are shown in Table C-3, for stations having 20 or more years of record.

Low Flows

Low flows occur on a yearly cyclical basis, having a three- or four-month duration. The time of low flows does not generally vary by more than about a month throughout the Region. Occasionally, or rather infrequently, a prolonged period of low flow extending beyond seasonal limits takes place, sometimes lasting for several years. In some basins, short duration extremes are often the result of the operation of upstream power plants.

The seasonal low flow period of the annual cycle is a natural occurrence, resulting from low rainfall and ground water outflow and high evapotranspiration. Least favorable runoff conditions occur during the summer and early fall, with the months of July through October generally have the lowest runoff. Four-month averages for this period range from about 10% to 15% of the long-term average runoff during very dry years. The minimum monthly occurrence for long-term stations has been as low as 1% of the average.

TABLE C-3

PEAK DISCHARGE-FREQUENCY[1]
(Discharge in 1,000 c.f.s.)

LOCATION	DRAINAGE AREA (Sq.Mi.)	DISCHARGE FREQUENCY Average Recurrence Intervals 100 Years	50 Years	20 Years	10 Years	2 Years
Penobscot R. at Veazie Dam, Me.	7,700	142	128	109	96	63
Kennebec R. at Augusta, Me.	5,470	185	157	123	101	59
Androscoggin R. nr Auburn, Me.	3,257	120	100	75	62	39
Merrimack R. at Lawrence, Mass.	4,461	136	115	95	81	53
Conn. R. at South Newbury, Vt.	2,825	79	70	58	50	34
Conn. R. at Middletown, Conn.	10,870	235	210	178	153	101
Housatonic R. at Gaylordsville, Conn.	994	45	36	26	20	11
Blackstone R. at Woonsocket, R.I.	416	24	19	14	10	5
Raquette R. at Piercefield, N.Y.	722	8	8	7	7	5
Saranac R. at Plattsburgh, N.Y.	608	12	10	9	8	5
Hudson R. at Hadley, N.Y.	1,664	44	40	34	30	20
Mohawk R. at Schenectady, N.Y.	3,306	129	112	94	82	60
Raritan R. at Bound Brook, N.J.	779	48	43	36	32	20
Lehigh R. at Bethlehem, Pa.	1,279	102	70	58	51	23

TABLE C-3 (Cont'd)

PEAK DISCHARGE-FREQUENCY(1)
(Discharge in 1,000 c.f.s.)

LOCATION	DRAINAGE AREA (Sq.Mi.)	DISCHARGE FREQUENCY Average Recurrence Intervals 100 Years	50 Years	20 Years	10 Years	2 Years
Del. R. at Trenton, N.J.	6,780	290	260	220	180	110
Schuylkill R. at Pottstown, Pa.	1,147	61	54	42	36	20
W. Br. Susquehanna R. at Williamsport, Pa.	5,682	278	242	200	169	95
Susquehanna R. at Danville, Pa.	11,220	270	250	215	190	130
Susquehanna R. at Harrisburg, Pa.	24,100	640	560	480	420	272
Potomac R. at Hancock, Md.	4,073	400	300	200	180	60
Potomac R. at Washington, D.C.	11,560	600	500	360	280	120
Rappahannock R. nr Fredericksburg, Va.	1,599	125	100	75	58	27
James R. at Holcombs Rock, Va.	3,250	128	111	94	80	52
James R. at Richmond, Va.	6,757	197	175	145	124	82

(1) Data selected from reports and studies generally prepared prior to 1967.

Streamflow throughout nearly the entire NAR was below the long-term average in the early 1960s, notably in 1964 and 1965, when water supplies were almost depleted at numerous locations because of deficient flows in the preceding two to three years.

Observed average annual streamflow on the St. John River, below the Fish River at Fort Kent, Me., was a record low of about 60% of the long-term average in Water Year 1965. The Androscoggin River at Auburn, Me., which had a record low of 59% of average in 1941, recorded the second lowest year with 61% of average in 1965. The Saco River at Cornish, Me., had a record annual low of 52% in Water Year 1965.

In southern New England, record annual lows of 44% of long-term average were established in Water Year 1965 at both Goffs Falls below Manchester, N.H., and below the Concord River at Lowell, Mass. in the Merrimack River Basin. In 1966, the flow was only 65% of average at Goffs Falls, and 60% at Lowell. Record annual lows throughout most of the main stem Connecticut River also occurred during Water Year 1965, with 72% at Dalton, N.H., 50% at Montague City, Mass., and about 50% at Thompsonville, Conn. On the Housatonic River at Falls Village and Stevenson, Conn., record lows were about 30% of average during the same period.

Streamflow was well below average in some Lake Champlain tributaries, as evidenced by a record low of 42% of average in 1965 on Otter Creek at Middlebury, Vt. Tributaries of the Hudson River below Albany, N.Y., established several records during 1965, such as Kinderhook Creek at Rossman, N.Y., with 35% of average, and the Walkill River at Pellets Island Mountain, N.Y., with 38%. The flow in the Hudson River at Green Island, N.Y., was 54% of average during the same Water Year, while further upstream at Hadley, N.Y., the flow was about 62%.

The average annual flow on the Delaware River at Montague, N.J., was 40% of the long-term average in Water Year 1965, replacing the 80% previous low observed in 1959. Low flows at Montague, N.J., for Water Years 1962 through 1966, were about 61% of average. The record low flow at Trenton, N.J., on the Delaware River in Water Year 1965 was 41% of average.

Further south in the Region, the Susquehanna River at Harrisburg, Pa., had a record observed low flow of about 50% of average in 1965. In Water Year 1966, a severe low flow of about 53% of average occurred on the Potomac River at Point of Rocks, Md. A previous low flow of approximately the same intensity occurred at the same location in 1931. An annual flow of 37% of average in 1966 on the James River at Cartersville, Va., replaced the previous record low of 52% in Water Year 1931.

Daily or instantaneous extreme low flows have generally occurred in late summer or early fall, often resulting from upstream regulatory effects. Observed short-duration flows for some gaging stations are shown in Table C-4. Information on seven-day low flows is included in Chapter 3 and the Sub-regional Summaries.

Figure C-6 shows the minimum for each month in extended records (through June 1967) at 10 selected stations. These data are derived from observed records, adjusted to natural conditions, and correlation analysis with long-term stations which provide synthesized, or reconstituted, values where there are no monthly flows. A detailed description of the methodology is included in Chapter 3. The data in Figure C-6 points out the fact that spring runoff is relatively high, even during low flow periods, and occurs somewhat earlier in the southern part of the Region. Increased variability, or departure from average, is also indicated in the spring low flows of southern basins.

Existing Storage Development

Table C-5 summarizes existing usable major storage by Area. The principal source of this data is "Reservoirs in the United States," Martin and Hanson, U.S. Geological Survey Water Supply Paper 1838, 1966. Projects of 5,000 or more acre-feet of usable storage completed or under construction as of January 1, 1963, were considered in this paper. For the purposes of the NAR Study, major projects completed since this date or under construction were added to the data in the referenced publication. These include the Round Valley-Spruce Run System in Area 14, Cannonsville in Area 15, Lake Raystown in Area 17 and Gathright Lake in Area 21.

Total usable storage capacity is nearly 16 million acre-feet, distributed as indicated in the Table. More detailed data on existing storage, as well as information on interbasin diversion activities, are presented in the Sub-regional Summaries.

GROUND WATER

Appendix D, Geology and Ground Water, indicates that large volumes of ground water, from a few million to several tens of millions of gallons a day per well field, are available in much of the Coastal Plain in the NAR; in belts of sandstone and carbonate rock, (limestone and dolomite), particularly where these have been folded and faulted; and in glacial sand and gravel beds which are generally adjacent to rivers and large streams. The average yield of wells in sandstone and carbonate rock are 150 gallons per minute (g.p.m.) and 300 g.p.m., respectively. In favorable locations, wells in Coastal Plain sediments may yield in excess of 2,000 g.p.m., and many wells in glacial deposits yield more than 700 g.p.m. Smaller quantities or ground water, generally less than 75 g.p.m., are available from wells in areas underlain by crystalline rocks and shale. Development in any one place is generally limited to not much more than 1 m.g.d.

According to Appendix D, the quality of the Region's ground

TABLE C-4
OBSERVED MINIMUM FLOWS

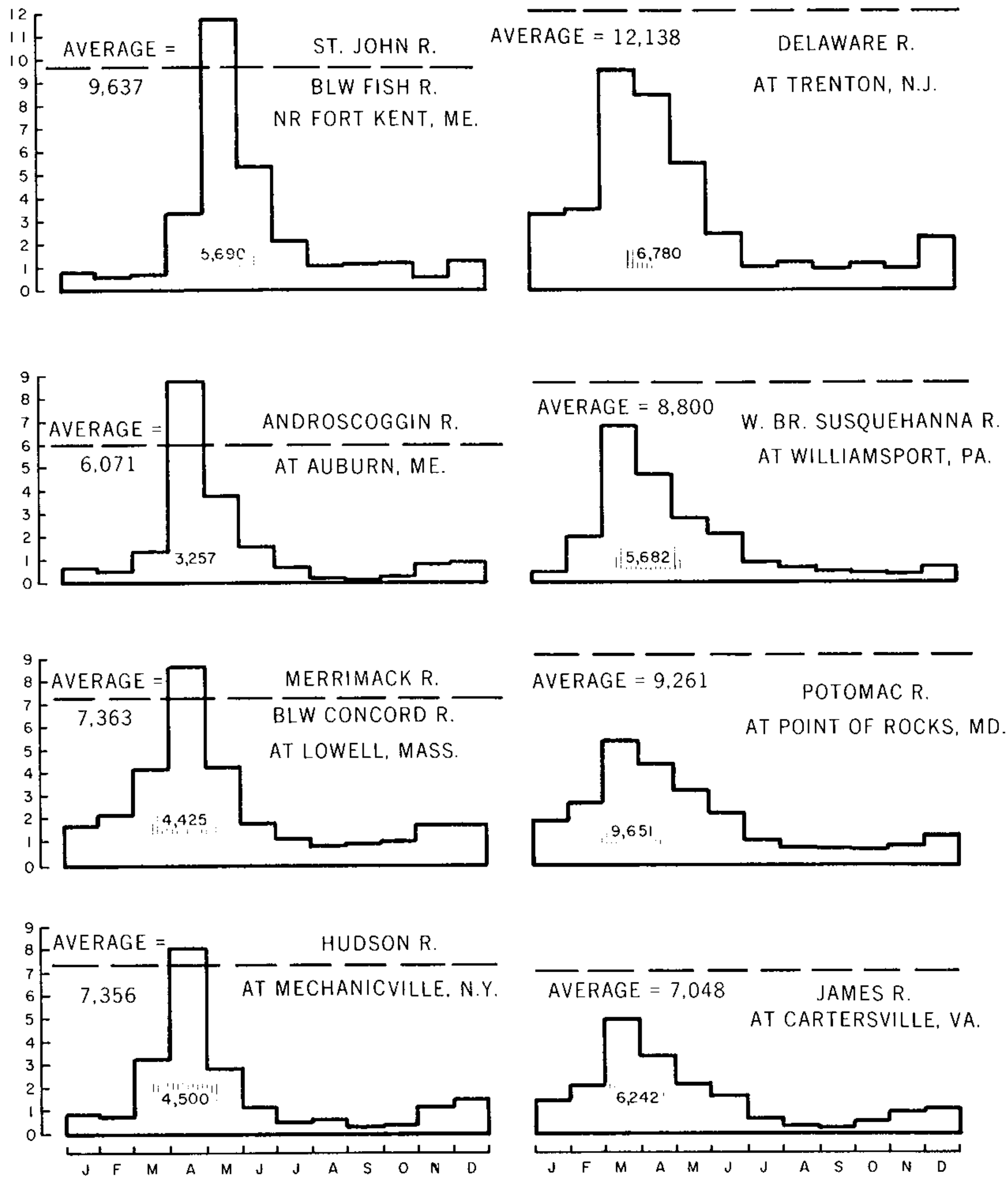
STATION	DRAINAGE AREA (Sq. Mi.)	OBSERVED MINIMUM FLOW (c.f.s.)1/	DATE
Allagash R. nr Allagash, Me.	1,250	87	Sept 11, 1960
St. John R. blw Fish R. nr Fort Kent, Me.	5,690	510*	Mar 13-15, 1948
Mattawamkeg R. nr Mattawamkeg, Me.	1,418	38	Sept 19, 1952
Kennebec R. at The Forks, Me.	1,589	85	Sept 3, 1953
Androscoggin R. nr Auburn, Me.	3,257	340*	Sept 28, 1941
Saco R. nr Conway, N. H.	386	40	Mar 16, 1932
Merrimack R. at Franklin Jct., N. H.	1,507	169	Aug 28, 1965
Merrimack R. blw Concord R. at Lowell, Mass.	4,425	199*	Sept 23, 1923
Conn. R. at White River Jct., Vt.	4,092	82*	Aug 8, 1905
Conn. R. at Thompsonville, Conn.	9,661	968	Oct 20, 1963
Grass R. at Pyrites, N. Y.	335	59	Aug 29, 1934
Walkill R. at Pellets Is. Mtn., N. Y.	385	3.2	July 1966 (4 times)
Mohawk R. at Cohoes, N. Y.	3,486	6	Sept 28, 1941
W. Branch Del. R. at Hale Eddy, N. Y.	593	17	Oct 20, 1903
Del. R. at Port Jervis, N. Y.	3,076	175	Sept 23, 1908
Del. R. at Trenton, N. J.	6,780	1,180	Oct 31, 1963
Schuylkill R. at Phila., Pa.	1,893	.6*	Sept 2, 1966 2/
Susquehanna R. at Wilkes-Barre, Pa.	9,960	538	Sept 27, 1964
Chenango R. at Chenango Forks, N. Y.	1,492	84	Sept 19 & 25, 1939
W. Br. Susquehanna R. at Williamsport, Pa.	5,682	162	Sept 17, 1943
Susquehanna R. at Harrisburg, Pa.	24,100	1,600	Nov 29, 1930
Monocacy R. at Jug Bridge nr Frederick, Md.	817	34*	Sept 15, 16, 1963
S. Br. Potomac R. nr Petersburg, W. Va.	642	42	Sept 28, 29, 1959
Potomac R. at Pt. of Rocks, Md.	9,651	530	Sept 11, 12, 1966
Rappahannock R. nr Fredericksburg, Va.	1,599	5	Oct 11, 12, 1930
North Anna R. nr Doswell, Va.	439	1	Sept 30, 1932
James R. at Scottsville, Va.	4,571	302	Oct 1, 1930
Appomattox R. nr Petersburg, Va.	1,335	19	Sept 21-27, 1932

1/ Instantaneous flows except asterisked values, which are mean daily flows.

2/ Below diversion point for Philedelphia municipal water supply(average 266 cfs in water years 1961 through 1965.

FIGURE C-6

MINIMUM MONTHLY VOLUMES
RECORDED AND RECONSTITUTED STREAMFLOW



NOTES:

ALL STATION RECORD LENGTHS = 80 YEARS EXCEPT W. BR. SUSQUEHANNA R. = 77 YEARS;

9,999 = DRAINAGE AREA IN SQUARE MILES/VERTICAL SCALE IS IN THOUSANDS OF CFS

TABLE C-5
EXISTING STORAGE DEVELOPMENT

	USABLE CAPACITY (1,000 acre-feet)	PRIMARY USES 1/
Area 1	96.8 2/	P
Area 2	1,723.9	P
Area 3	1,386.4	P
Area 4	764.3	P
Area 5	883.0 2/	PR
SUB-REGION A	4,854.4	-
Area 6	406.9	PR
Area 7	911.1	MPR
Area 8	2,609.6	FMPR
Area 9	158.7	M
Area 10	416.8	FPR
SUB-REGION B	4,503.1	-
Area 11	482.9	P
Area 12	2,010.8	FMNP
Area 13	89.6	M
SUB-REGION C	2,583.3	-
Area 14	401.4	M
Area 15	1,405.7	MP
Area 16	7.4	W
SUB-REGION D	1,814.5	-
Area 17	1,459.1	FM
Area 18	300.2	MR
SUB-REGION E	1,759.4	-
Area 19	55.8	FMPR
Area 20	-	-
Area 21	221.3	FM
SUB-REGION F	277.1	-
TOTAL NAR	15,791.8	-

1/ F = Flood Control; M = Municipal; N = Navigation; P = Power; ;
R = Recreation; W = Industrial.

2/ Does not include storage in contributing drainage areas in Canada.

water is generally good. In carbonate rock areas, the water is hard; in glacial sediments, undesirable amounts of iron or manganese are not uncommon; and wells in Coastal Plain sediments may yield water that is too high in chloride and other constituents to be useful for most purposes.

Although, for the most part, hydrologic data and analysis in Appendix C rely on surface streamflow information, it is recognized that surface water and ground water are elements of the same hydrologic system. Ground water contributions account for a large part of the flow in the Region's rivers -- in fact, practically all during dry periods.

During periods of rainfall or rapid snowmelt, the rate of natural recharge to ground water storage is greater than the outflow from that storage to the streams and consequently, the water table rises. The water table then declines slowly during periods of little or no precipitation.

Withdrawal of water from either surface or ground supplies will, in many cases, merely subtract from the water available from the other source. For example, in the case of ground water withdrawal, the pumping of aquifers might intercept ground water outflow to the streams, or simply induce infiltration directly from the streams.

Further, and considerably more detailed, information on ground water availability and the ground water-surface water relationship is contained in Appendix D.

CHAPTER 3. REGIONAL ANALYSES

ANALYSIS OF WATER AVAILABILITY - MAJOR RIVER STORAGE

Some 144 streamflow gaging stations were used as key stations in this analysis. These stations were selected so as to provide for the use of the longer available records, to provide appropriate areal coverage, and to divide the major gaged portions of the Region into Sub-basins that would be consistent in size with the purposes and scope of the NAR Study. The adopted stations gage a total drainage area of about 116,000 square miles and the average incremental or local area -- the drainage area at the upstream gage on a river or the area between successive gages on a river -- is on the order of 800 square miles.

A large portion of the monthly streamflow records for the key stations were obtained on punched cards from the U.S. Geological Survey. In order to utilize all available flows through June 1967, it was necessary to supplement these data with monthly records in published surface water supply papers and, in a few cases, with provisional data furnished by Geological Survey. Record lengths for the key stations vary from 16 to 79 years. Five stations have record lengths from 70 to 79 years, 23 from 60 to 69 years, 31 from 50 to 59 years, 34 from 40 to 49 years, 33 from 30 to 39 years, and the remaining 18 less 30 years.

At those stations where monthly flows were significantly affected by regulation or diversion upstream, flows as adjusted to natural conditions were obtained, if available, or appropriate adjustments to observed flows were made using data records of changes in reservoir contents and diversion.

Tables containing pertinent information on key stations and schematic diagrams showing the relative location of each station are included in the Sub-regional Summaries.

STREAMFLOW SIMULATION

The estimation of missing monthly data in key station records, including completion of records through June 1967, and the generation of synthetic monthly streamflow traces were accomplished by means of computer. The program utilized was "Monthly Streamflow Simulation," Corps of Engineers Hydrologic Engineering Center Program 23-CL*-267, July 1967.

This program analyzes monthly streamflows at up to ten interrelated stations to determine statistical characteristics -- the mean, standard deviation and skew coefficient for each calendar month at each station, the correlation between consecutive months at each station, and the correlation between stations. Missing monthly data in the historic records are then mathematically reconstituted on the basis of correlation matrices adjusted for consistency, the concurrent and preceding monthly flows at interrelated locations, and a random component equal to the non-determination in the regression equation for each calendar month. The reconstitution of missing records extends all stations to the same base length, which is desirable for working purposes, and takes advantage of the longest records available in each group of stations. This step of the program made it possible to approximate all NAR records through June of 1967, even though complete data were not available for all key stations to this date.

In the statistical analysis portion of this program, as described in "Monthly Streamflow Simulation," U.S. Army Corps of Engineers Hydrologic Engineering Center, Manual HEC-4, February 1971, the flows for each calendar month at each station are incremented by a small percentage of their calendar month average. Mean, standard deviation and skew coefficients are computed for each station and each month. For each station and month with an incomplete record, the longer records are searched to find the one which will contribute the most toward increasing the reliability of the statistics of the incomplete records. The mean and standard deviation are then adjusted based on the equivalent record length computed from the best longer record station.

Each individual flow is then converted to a normalized standard variate, using the following approximation of the Pearson Type III distribution:

$$t_{i,m} = (X_{i,m} - \overline{X}_i) / S_i \quad \text{(Equation a)}$$

$$K_{i,m} = 6/g_i \left[((g_i t_{i,m}/2) + 1)^{1/3} - 1\right] + g_i/6 \quad \text{(Equation b)}$$

In which:

X = Logarithm of incremented monthly flow

$\overline{X}$ = Mean logarithm of incremented monthly flow

S = Standard deviation

g = Skew coefficient

i = Month number

m = Year number

t = Pearson Type III standard deviate

K = Normal standard deviate

After the flows for all stations and months are transformed, the gross (simple) correlation coefficients R between all pairs of stations for each current and preceding month are computed by:

$$R_i = \left\{1 - \left[1 - \left(\sum_{m=1}^{N} x_{i,m}x_{i-1,m}\right)^2 / \left(\sum_{m=1}^{N} x^2_{i,m} \sum_{m=1}^{N} x^2_{i-1,m}\right)\right] (N-1)/(N-2)\right\}^{1/2} \quad \text{(Equation c)}$$

In which:

$$x = X - \overline{X} \quad \text{(Equation d)}$$

If a small number of simultaneous obsevations exist between variable pairs, an estimated value is obtained by examining its relationship to related pairs of values in the current and preceding month, where i, j and k subscripts indicate the variables used in the gross correlation:

$$R_{ij} = R_{ki}R_{kj} \pm \sqrt{(1 - R_{ki}^2)\ (1 - R_{kj}^2)} \quad \text{(Equation e)}$$

The estimated correlation coefficient must lie between the two values resulting from this equation in order to be consistent with the two related coefficients, and the average of the two values is used as the estimated correlation coefficient.

Missing monthly flows are then estimated for all stations for each month, in turn, so that whenever a missing flow is being reconstituted, there always exists a valid value for all stations previously examined in that month, and for all remaining stations in the current or preceding month. A regression equation using normal standard variates is computed and used to reconstitute the missing flow. The variate is found by selecting required coefficients from the completed correlation matrix for that month, and solving by the Court method (previous reference Manual HEC-4) of solutions for simultaneous linear equations.

This regression technique requires that correlation coefficients be mutually consistent in order to be valid. Inconsistency is evidenced by a determination coefficient (R^2) greater than 1.0, which is due to incomplete data. If this occurs, the independent variable which contributes least to the correlation is repetitively dropped until consistency is reached in the new regression equation. In order to make the correlation matrix consistent with the data matrix, all effected coefficients are recomputed after each estimate of missing data.

Monthly streamflows are obtained by solving Equation b for $t_{i,m}$ and using this value to compute $X_{i,m}$ in Equation a. Then:

$$Q_{i,m} = \text{Antilog } X_{i,m} - qi \quad \text{(Equation f)}$$

in which q_i is the increment previously added. The lone constraint is:

$$Q_{i,m} \geqslant o \quad \text{(Equation g)}$$

The generation of hypothetical streamflow is accomplished by solving a linear regression equation for each month at each station by the Crout method, and then computing the flow for each station, one month at a time, using the following equation:

$$K'_{i,j} = \beta_1 K'_{i,1} + \beta_2 K'_{i,2} + \cdot \cdot \cdot + \beta_{j-1} K'_{i,j-1} + \beta_j K'_{i-1,j} +$$

$$\beta_{j+1} K'_{i,1,j+1} + \cdot \cdot \cdot + \beta_n K'_{i-1,n} + \sqrt{1-R^2_{i,j}} \cdot Z_{i,j} \quad \text{(Equation h)}$$

In which:

K = Monthly flow logarithm, expressed as a normal standard deviate

β = Beta coefficient computed from correlation matrix

i = Month number

j = Station number

n = Number of interrelated stations

R = Multiple correlation coefficient

Z = Random number

The process is begun using average values for all stations in the first month, and discarding the first two years of generated flow.

Tables C-6 through C-9 are samples of the analysis of the monthly data. Table C-6 lists the frequency statistics for the four stations. The names corresponding to the station numbers are in the Subregion A Summary. The values shown are the logarithms of mean, standard deviation and skew for each calendar month. The number 1 in the heading represents January and 12 represents December. The line showing increment indicates an amount which has been added to the flow at each station to avoid obtaining large negative logarithms. This is later deducted from generated flows.

Table C-7 shows the consistent matrix representing the adjusted correlation coefficients between station pairs for concurrent and preceding monthly flow in January and February (1 and 2). The adjustment is based on the adjusted frequency statistics of the extended records. Table C-8 illustrates the output of reconstituted record at

TABLE C-6
FREQUENCY STATISTICS - SAMPLE OUTPUT

ADJUSTED FREQUENCY STATISTICS

STA	ITEM	1	2	3	4	5	6	7	8	9	10	11	12
152	MEAN	3.174	3.035	3.363	4.032	3.983	3.507	3.171	2.993	3.023	3.239	3.470	3.298
	STD DEV	.224	.248	.338	.132	.184	.247	.292	.339	.377	.368	.274	.278
	SKEW	-.380	-.223	.680	-.188	-.983	-.263	-.511	-.461	-.246	-.793	-.463	-.260
	INCRMT	19.90	14.75	38.50	133.71	122.64	44.43	21.38	15.25	18.31	27.55	42.11	28.69

STA	ITEM	1	2	3	4	5	6	7	8	9	10	11	12
117	MEAN	2.704	2.554	2.602	3.379	3.687	3.255	2.957	2.763	2.657	2.718	2.949	2.912
	STD DEV	.232	.191	.243	.257	.141	.168	.247	.349	.370	.360	.363	.324
	SKEW	-.257	-.312	.736	-.588	-.302	.560	.345	.944	.374	-.056	-.487	-.354
	INCRMT	6.85	4.67	5.71	32.04	61.28	21.81	12.02	8.13	6.45	7.40	13.48	12.07

STA	ITEM	1	2	3	4	5	6	7	8	9	10	11	12
158	MEAN	3.021	2.913	3.007	3.865	3.983	3.494	3.210	2.992	2.935	3.176	3.366	3.253
	STD DEV	.298	.258	.389	.229	.168	.260	.304	.341	.416	.400	.377	.374
	SKEW	-1.132	-.103	.258	-.884	-.779	-.704	-.811	-.547	-.600	-.940	-1.000	-1.033
	INCRMT	14.74	11.54	18.15	99.59	118.28	45.20	23.79	15.73	14.45	23.46	34.82	26.67

STA	ITEM	1	2	3	4	5	6	7	8	9	10	11	12
115	MEAN	2.959	2.806	2.913	3.991	4.172	3.697	3.482	3.371	3.318	3.477	3.525	3.277
	STD DEV	.214	.216	.253	.234	.189	.251	.282	.315	.324	.285	.312	.262
	SKEW	-.201	-.289	.212	-.465	.561	-.447	.136	-.270	-.037	.030	-.616	.032
	INCRMT	14.44	10.10	12.78	142.26	190.08	58.44	33.87	29.12	27.97	34.83	52.28	33.96

STA	ITEM	1	2	3	4	5	6	7	8	9	10	11	12
114	MEAN	2.648	2.516	2.592	3.696	3.828	3.343	3.107	3.013	2.974	3.181	3.233	2.968
	STD DEV	.188	.187	.277	.224	.173	.286	.260	.422	.363	.301	.298	.305
	SKEW	.054	-.140	.437	-.315	.427	-.293	-.791	-.570	-.388	.097	-.261	.883
	INCRMT	6.88	4.94	6.28	71.81	86.27	24.78	14.27	15.04	14.59	18.51	28.59	23.42

STA	ITEM	1	2	3	4	5	6	7	8	9	10	11	12
116	MEAN	2.716	2.546	2.645	3.486	3.821	3.390	3.129	2.995	2.927	2.966	3.073	2.933
	STD DEV	.224	.208	.245	.275	.157	.173	.224	.322	.314	.291	.299	.286
	SKEW	-.133	-.009	1.005	-.914	-.055	.201	-.206	.496	.483	-.053	-.338	.081
	INCRMT	7.70	5.22	6.87	46.01	83.53	29.51	18.38	12.75	11.33	13.22	18.85	14.22

STA	ITEM	1	2	3	4	5	6	7	8	9	10	11	12
169	MEAN	2.869	2.660	2.852	3.839	3.903	3.413	3.088	2.906	2.853	3.060	3.312	3.127
	STD DEV	.257	.282	.330	.208	.170	.245	.326	.379	.373	.367	.355	.378
	SKEW	-.392	-.265	.797	-.947	.466	.414	.584	.934	.528	-.419	-.804	-.996
	INCRMT	10.39	7.02	13.67	94.79	103.66	30.91	17.63	11.05	10.68	16.64	33.09	23.74

STA	ITEM	1	2	3	4	5	6	7	8	9	10	11	12
118	MEAN	3.389	3.230	3.327	4.256	4.509	4.050	3.797	3.686	3.605	3.714	3.806	3.625

TABLE C-7
CONSISTENT MATRIX - SAMPLE OUTPUT

CONSISTENT CORRELATION MATRIX FOR MONTH 1

STA	152	117	158	115	114	116	169	118
			WITH CURRENT MONTH					
152	1.000	.497	.574	.524	.502	.533	.525	.563
117	.497	1.000	.713	.822	.788	.924	.815	.883
158	.574	.713	1.000	.793	.828	.720	.821	.738
115	.524	.822	.793	1.000	.959	.882	.834	.930
114	.502	.788	.828	.959	1.000	.846	.800	.892
116	.533	.924	.720	.882	.846	1.000	.860	.948
169	.525	.815	.821	.834	.800	.860	1.000	.884
118	.563	.883	.738	.930	.892	.948	.884	1.000
			WITH PRECEDING MONTH AT ABOVE STATION					
152	.373	.409	.406	.431	.385	.417	.410	.426
117	.741	.818	.811	.863	.771	.834	.819	.852
158	.593	.629	.625	.664	.593	.642	.631	.656
115	.612	.676	.671	.713	.637	.689	.677	.704
114	.587	.648	.643	.684	.611	.661	.649	.675
116	.684	.755	.749	.797	.712	.770	.757	.787
169	.604	.667	.662	.703	.628	.680	.668	.694
118	.658	.726	.721	.766	.685	.741	.728	.757

CONSISTENT CORRELATION MATRIX FOR MONTH 2

STA	152	117	158	115	114	116	169	118
			WITH CURRENT MONTH					
152	1.000	.715	.689	.812	.754	.707	.711	.755
117	.715	1.000	.771	.881	.854	.901	.832	.947
158	.689	.771	1.000	.848	.903	.762	.804	.814
115	.812	.881	.848	1.000	.928	.870	.876	.931
114	.754	.854	.903	.928	1.000	.844	.813	.902
116	.707	.901	.762	.870	.844	1.000	.810	.935
169	.711	.832	.804	.876	.813	.810	1.000	.866
118	.755	.947	.814	.931	.902	.935	.866	1.000
			WITH PRECEDING MONTH AT ABOVE STATION					
152	.526	.597	.513	.548	.525	.589	.521	.589
117	.586	.835	.680	.751	.720	.788	.713	.807
158	.558	.644	.639	.690	.719	.635	.575	.642
115	.576	.736	.631	.675	.647	.726	.642	.725
114	.558	.713	.595	.654	.649	.703	.622	.703
116	.579	.770	.704	.774	.742	.834	.736	.832
169	.535	.694	.721	.680	.681	.675	.676	.675
118	.619	.791	.660	.725	.695	.780	.690	.780

CONSISTENT CORRELATION MATRIX FOR MONTH 3

STA	152	117	158	115	114	116	169	118
			WITH CURRENT MONTH					
152	1.000	.619	.674	.715	.740	.608	.690	.656
117	.619	1.000	.796	.835	.806	.894	.898	.910
158	.674	.796	1.000	.903	.890	.780	.763	.828

TABLE C-8
SAMPLE MONTHLY OUTPUT
RECORDED AND RECONSTITUTED STREAMFLOWS
(c.f.s.)

152	1943	753	952	2061	6762	17820	7355	1595	2832	2130	4715	6465	1739	55179
152	1944	1004	670	1057	8262	15848	3445	1864	555	1426	3119	2556	1972	41778
152	1945	2259	754	9160	15320	11330	3390	2205	663	1926	4894	3390	2527	57818
152	1946	1828	1290	10003	8077	7565	2278	573	1936	833	4374	3946	3280	45983
152	1947	2402	3632	3424	10707	16583	6947	2510	448	444	35	1018	770	48920
152	1948	268	287	4643	11096	12172	2260	753	358	361E	519	4335	1398	38459
152	1949	3442	992	3065	11300	5737	2297	591	933E	463	627	1963	2689	34099
152	1950	3496	1429	2366	13078	8157	3797	1255	968	704	878	7892	7314	51334
152	1951	1326	2640	2510	19692	7888	1611	1846	968	1018	1183	6613	3944	51239
152	1952	1972	1437	1667	16209	10810	6298	161	89	111	376	778	2079	41987
152	1953	1721	2004	12674	15190	8336	1315	735	519	222	878	2834	4033	50461
152	1954	1039	1786	2743	17895	13391	6428	3227	2527	9799	6077	5354	3334	73600
152	1955	1631	1548	1936	15894	8891	4372	466	1882	439E	717	3168	555	41499
152	1956	3962	1034	932	7651	14449	3575	1721	412	1685	1488	1945	1792	40646
152	1957	1523	1250	2115	8170	5647	1722	2456	770	500	753	4557	9053	38516
152	1958	2294	1071	1344	17543	11885	2593	3370	1434	1148	3547	3205	1039	50493
152	1959	1649	972	1272	14153	5683	6391	1344	1021	1000	7279	9466	5647	55877
152	1960	2151	1839	1021	17525	11867	3093	1416	430	1982	2335	2578	1491	47728
152	1961	626	1363	2224	8659	14239	4126	1770	565	576	351	1732	1597	37828
152	1962	1049	861	1271	14029	10019	1374	1511	3362	1749	5899	6389	2954	50467
152	1963	1199	664	1517	11239	10599	1078	1420	1829	954	642	10039	3581	44761
152	1964	1895	974	3036	10939	5714	1261	2100	962	306	560	2598	2431	32776
152	1965	1239	1047	1249	5314	6146	1714	700	1068	1711	3488	2651	1057	27384
152	1966	1296	1323	3836	9013	10049	3381	459	938	546	1465	4359	2350	39015
152	1967	947	511	821	7639	11999	3553	2645F	2257F	1903E	2876F	2446E	1929F	39526

STA	YEAR	1	2	3	4.	5	6	7	8	9	10	11	12	TOTAL
117	1892	565E	379E	311E	4485E	5996E	2491E	2443E	1449F	825E	1453E	1385E	1485E	23267
117	1893	591E	333E	265E	1451F	12105E	4724E	1110E	2338F	3830E	1051E	1595E	595E	29988
117	1894	390E	452E	303E	2480F	2998F	2871E	1298E	801F	587E	799E	1316E	906E	15201
117	1895	363E	414E	253E	3108E	4084E	867E	1214E	1513F	635E	625E	1581E	2046E	16703
117	1896	873E	466E	376E	3436E	4331E	1295E	1280E	541F	1045E	1418E	1069E	609E	16739
117	1897	471E	256E	416E	2704E	4203E	2157E	3085E	2710F	1081E	457E	1304E	2160E	21004
117	1898	955E	516E	1180E	3612E	5285E	2978E	965E	1262E	863E	1043E	886E	423E	19968
117	1899	309E	261E	174E	1008E	7576E	2019E	868E	407F	138E	274E	495E	407E	13936
117	1900	202E	367E	747E	4105E	5304E	1493E	2001E	925F	972E	1388E	998E	921E	19423
117	1901	519E	295E	746E	4051E	5089E	1281E	945E	1850F	659E	386E	112E	907E	17040
117	1902	671E	687E	1666E	5336E	5599E	4879E	922E	571F	1068E	1244E	1768E	656E	25067
117	1903	644E	367E	611E	4920E	4760E	1539E	1056E	484	242	94	206	215	15138
117	1904	149	116	202	1170	6360	2025	742	392	898	1513	727	364	14658
117	1905	227	174	144	1560	2700	1514	597	158	74	63	98	142	7451
117	1906	181	212	336	954	6330	2010	753	206	93	419	860	576	12930
117	1907	484	238	203	838	6120	3040	1920	2070	817	1330	2480	1220	20760
117	1908	731	433	463	1790	7090	2490	670	485	302	150	120	150	14874
117	1909	374E	348E	222F	3773E	6937E	1477F	520F	235E	563E	768E	840F	377E	16434
117	1910	245F	320F	417F	2905E	3854E	1723F	375F	324F	284E	363E	534E	467E	11811
117	1911	226F	244E	237F	780E	4848E	1140	429	445	300	187	168	1491E	10495
117	1912	817F	465E	567F	2979F	4942E	2090F	417F	377E	877E	457E	2166E	1288E	17442
117	1913	559E	416E	528F	3447E	3579E	1075F	847E	263E	215E	584E	2028E	1161E	14702
117	1914	877E	361E	266F	1300F	6350E	2126F	491E	467E	860F	435E	650E	309E	14492
117	1915	301E	242E	308F	1310F	3238E	917F	1326E	1193E	1060F	629E	389F	664E	11577
117	1916	608F	541E	708F	3065E	4092E	2114F	1067E	1654E	867E	1108E	1701E	858E	18383
117	1917	378F	312E	418F	1713F	4434E	6088F	1208E	3551E	1444E	829E	1083F	445E	21943
117	1918	231E	196E	209F	2731F	4350E	1702E	2294E	1218E	1367F	949E	2124E	2000E	19371
117	1919	1235F	503E	624F	3171F	4366E	1725F	428E	898E	527F	758E	2276E	1128E	17639
117	1920	439F	363F	285F	3593F	5495E	1279F	1049E	350E	888F	1570E	2252E	2099E	19662

the station, showing the estimated flows with the designation "E" following the number. Table C-9 shows the maximum and minimum flow for each month, the extreme 1-, 6- and 54-month occurrences, and also the average monthly flow for recorded and reconstituted record.

In the final step, the program mathematically generates a sequence, or sequences, of hypothetical or synthetic monthly flows of any desired length. These traces essentially preserve the mean, standard deviation and skew characteristics of the input as well as the cross-station correlation and the serial correlation between consecutive months, and include a random component each month to provide the variance not explained by correlation.

Streamflow simulation supplements drought data of record by providing hypothetical streamflow traces which are as likely to occur in the future as a recurrence of the historic data. This aspect has been tested by various means, including split-record tests in which one half of a record and synthetic sequences of the same length based on this record, are used to estimate various quantities of runoff, storage, etc., which can then be compared with the same items as derived from the second half of the actual record.

For the purposes of the NAR Study, 1,000 years of synthetic monthly streamflow were generated at each station in 10 separate 100-year sequences. The results are listed as program output in the same format as shown in Table C-8 (p. C-31). Figure C-7 indicates the results of a simulation for the Susquehanna River at Karthaus, Pa. In this sample, the recorded and recorded and reconstituted records are compared with five of the generated periods. It can be seen that April is the only month in which the historic minimum is as severe as that generated in the other 500 years shown.

On the other hand, in March, May, June, September and October the minimum for each of the 100-year periods is less than that in the historic record. Referring to the curves of maximum flow, both the recorded flow and the recorded and reconstituted flow are equal in the month of April and higher than any of the 100-year generated periods shown. In all other months, one or more of the generated periods is higher. The lowest maximum is obtained in the recorded flows in seven of the 12 months, and the recorded and reconstituted flows are lower than any of the five generated traces in both February, August and October. The highest maximum monthly occurrence in all 10 generated periods was more than 28,000 c.f.s., or more than twice the historic flow of 12,700 c.f.s.

Extremes more severe than the historic record would be expected in simulating flows for as long as 500 years, depending on the position of the historic extreme with respect to the population which can be generated with the statistics for that month. As might be surmised from Figure C-7, a general seasonal variation similar to that of the historic record is preserved, and generated monthly flows in sequence look much

TABLE C-9
SAMPLE OF MAXIMUM AND MINIMUM VOLUMES
RECORDED NAD RECONSTITUTED STREAMFLOWS
(c.f.s.)

MAXIMUM VOLUMES FOR PERIOD 1 OF 76 YEARS OF RECORDED AND RECONSTITUTED FLOWS

STA	1	2	3	4	5	6	7	8	9	10	11	12	1-MO	6-MO	54-MO	AV MO
152	4356	3672	23520	19692	21280	12615	7117	3926	9799	7279	10781	9053	23520	53267	254496	3664
117	1891	982	3104	7495	12105	6088	3400	4225	3830	2215	4116	4686	12105	25558	100610	1381
158	3164	2531	11397	17203	20049	13283	6080	5914	7309	8498	9205	8912	20049	43621	222801	3132
115	2669	1949	2535	22589	93480	23066	21800	9361	10204	9430	12291	9780	93480	126461	371240	4594
114	1325	899	1593	12221	32986	14944	3843	6574	4860	5281	7004	9890	32986	49225	171117	2184
116	1865	1144	3560	8698	20147	7774	4053	6303	5806	3776	4674	4549	20147	39471	132423	1850
169	2679	1729	10831	15857	29537	14396	10172	11878	5241	5058	9857	8110	29537	49419	187716	2628
118	7438	4230	23588	45567	109947	39177	15737	21686	14699	17609	24198	22899	109947	175000	642924	9256

MINIMUM VOLUMES

STA	1	2	3	4	5	6	7	8	9	10	11	12	1-MO	6-MO	54-MO	AV MO
152	268	249	537	4705	1972	518	161	89	74	35	314	268	35	2822	152230	
117	149	116	107	390	1959	867	294	135	74	63	98	103	63	716	54362	
158	82	194	146	1574	3048	308	183	82	34	66	119	33	33	1534	131591	
115	253	201	103	2073	5598	1186	727	265	397	586	374	501	103	3406	174406	
114	150	139	71	1049	2593	529	174	22	102	347	293	286	22	1700	83200	
116	152	111	173	406	2022	1094	365	241	213	134	239	207	111	1432	72086	
169	165	91	100	1554	3164	985	275	186	118	77	177	42	42	1412	100273	
118	772	562	669	2718	9652	5372	2135	1038	1105	1146	571	1150	562	7083	354891	

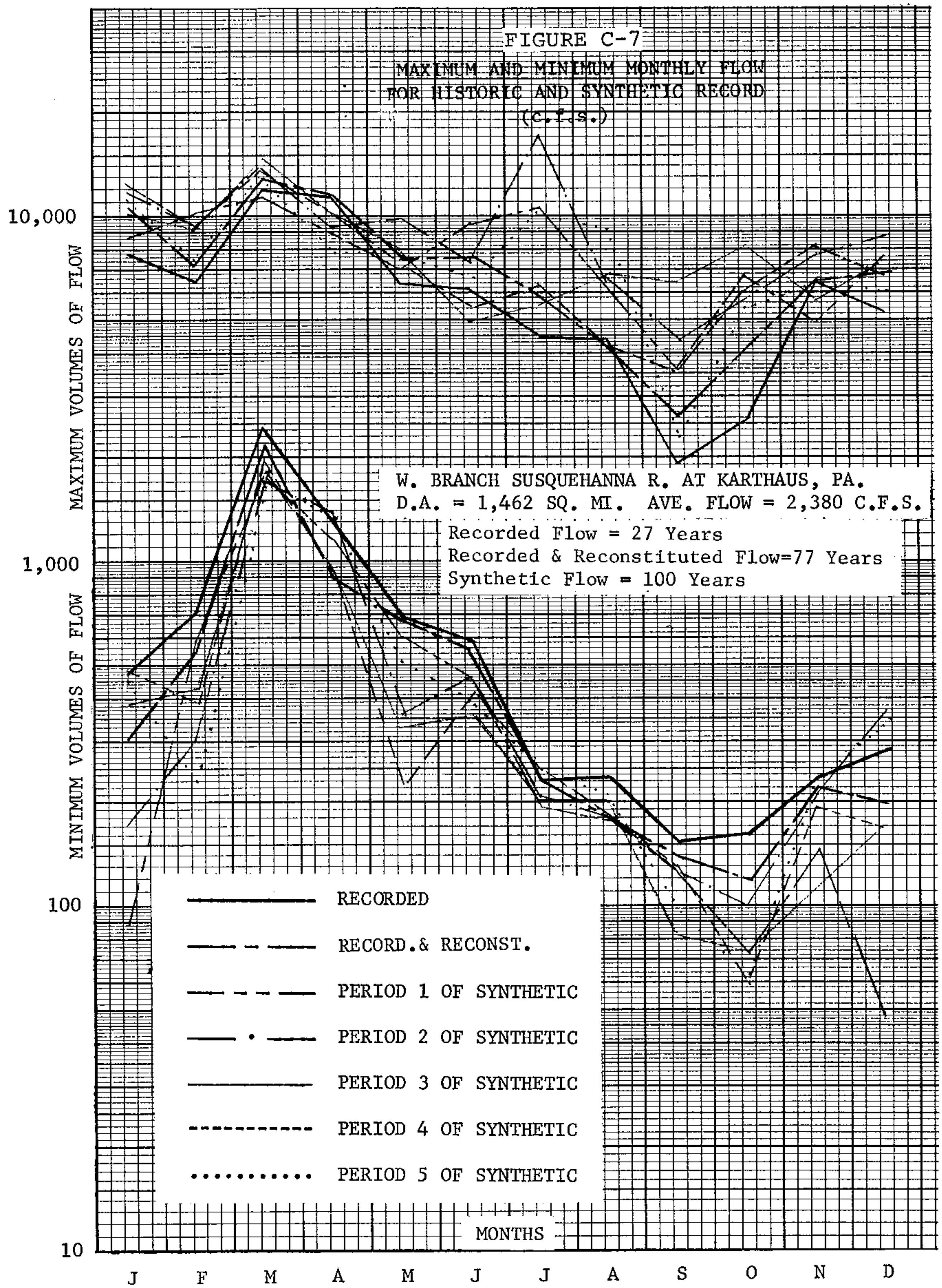


FIGURE C-7
MAXIMUM AND MINIMUM MONTHLY FLOW
FOR HISTORIC AND SYNTHETIC RECORD
(c.f.s.)
W. BRANCH SUSQUEHANNA R. AT KARTHAUS, PA.
D.A. = 1,462 SQ. MI. AVE. FLOW = 2,380 C.F.S.
Recorded Flow = 27 Years
Recorded & Reconstituted Flow=77 Years
Synthetic Flow = 100 Years
MAXIMUM VOLUMES OF FLOW
MINIMUM VOLUMES OF FLOW
10,000
1,000
100
10
RECORDED
RECORD.& RECONST.
PERIOD 1 OF SYNTHETIC
PERIOD 2 OF SYNTHETIC
PERIOD 3 OF SYNTHETIC
PERIOD 4 OF SYNTHETIC
PERIOD 5 OF SYNTHETIC
MONTHS
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like the historic record.

A further indication of simulation results is given in Table C-10, where the historic period is compared with 1,000 years of generated streamflow, for the Susquehanna River at Karthaus, Pa., in terms of 6- and 54-month volumes. The synthetic data represent the highest and lowest 100-year traces with respect to the specified volumes. Information of this nature for most key stations is contained in the Subregional Summaries.

TABLE C-10
MAXIMUM AND MINIMUM VOLUMES FROM HISTORIC AND GENERATED STREAMFLOWS
KARTHAUS, PA.
(Cubic feet per second)

	6 MONTHS		54 MONTHS	
	Maximum	Minimum	Maximum	Minimum
Historic	35,617	1,244	168,286	84,079
Generated High	49,436	1,738	211,424	95,168
Generated Low	35,060	1,090	169,295	77,494

It is entirely possible that at some stations, the period of record would represent much more severe conditions than most of the generated traces. An example of this will be shown in connection with the discussion of yield-storage analyses.

SHORTAGE INDEX

The shortage index has been used as the risk criteria for the yield-storage and minimum flow analyses to be discussed later. This index weighs both the number of shortages in a hundred years and their severity. It is described as equal to the sum of the squares of the annual shortages over a 100-year period, where each shortage is expressed as a ratio to the annual requirement. It follows that the numerical value of the index varies in direct proportion to the number of shortages and the square of the shortage quantities, at a given demand. Thus, in Table C-11, one annual shortage of 10% in 100 years would be equivalent to an index of 0.01 and one shortage of 20% in 100 years would be equivalent to an index of 0.04.

TABLE C-11
EXAMPLES OF COMPUTATION OF SHORTAGE INDEX

ANNUAL SHORTAGES PER 100 YEARS	ANNUAL SHORTAGE PERCENTAGE	SHORTAGE INDEX
1	10	$(0.10)^2 = 0.01$
1	20	$(0.20)^2 = 0.04$
5	10	$5(0.10)^2 = 0.05$
10	20	$10(0.20)^2 = 0.40$

The shortage index concept is based on the observation that economic and social consequences of drought periods are about proportional to the square of the degree of shortage. Since the index reflects the magnitude of shortage as well as the number of shortages, it has considerable merit over frequency alone as a criterion, and it could possibly be multiplied by a constant to obtain an estimate of damages.

In actuality, the computation of shortage index would seldom be as simple as shown in Table C-11. The index would most often represent a number of deficient years of widely varying shortage. For example, if, in a 100-year period with a constant monthly demand of 1,000 c.f.s., there was a six-month shortage of 400 c.f.s. (2,400 c.f.s.-months) in one year and a four-month shortage of 300 c.f.s. (1,200 c.f.s.-months) in another year, the shortage index would be computed as follows:

$$\text{S.I.} = \left[\frac{2,400}{12 \times 1,000}\right]^2 + \left[\frac{1,200}{12 \times 1,000}\right]^2 = .04 + .01 = .05$$

Where there is a monthly variation in flow requirement, it is necessary to calculate monthly shortages, sum and square for each year. If the period of analysis is less than 100 years, the calculated shortage index would be adjusted by multiplying it by the ratio of 100 divided by the period of record used.

Figure C-8 further illustrates the relationships described by the definition of shortage index, by depicting theoretical shortage versus number of shortage combinations for a wide range of indices. It should be noted that many combinations are possible. For example, although two 10% shortages would result in an index of 0.02, one 10% shortage and two 7% shortages would also be equivalent to an index of 0.02.

The scale at the extreme left of the Figure is useful for relating an equivalent three-month shortage to a given annual shortage. On the basis of a sampling of data from NAR analyses, three months has been found to be a fair estimate of the average length of shortage for comparative purposes. Obviously, the maximum duration of shortage could be considerable longer depending on the requirements, the storage, if

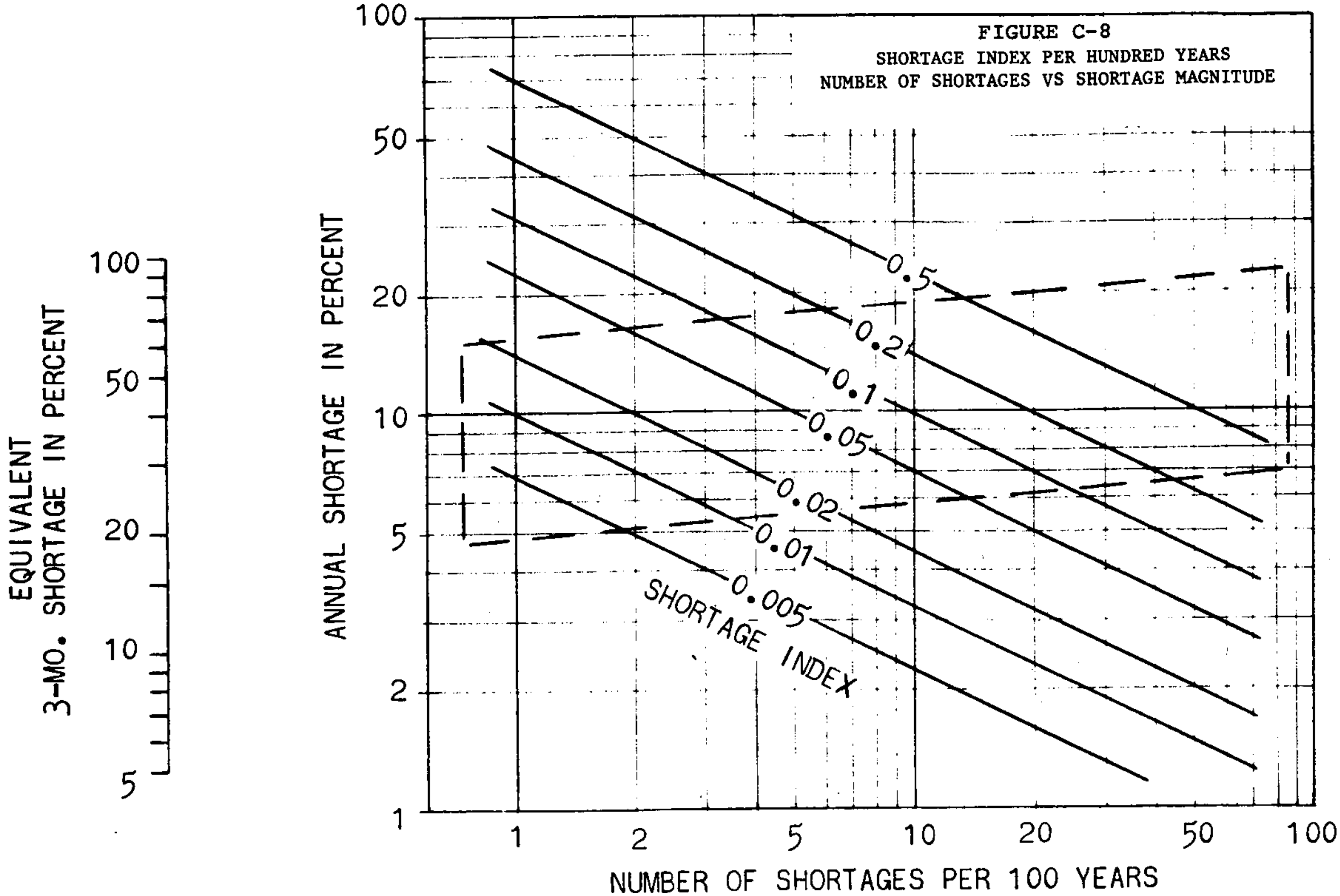


FIGURE C-8
SHORTAGE INDEX PER HUNDRED YEARS
NUMBER OF SHORTAGES VS SHORTAGE MAGNITUDE

any, and the shortage index. The dashed parallelogram on the chart serves to focus attention on the most-likely areas and is based on data from the NAR yield-storage analyses for a wide variety of storage, yield, and shortage index combinations. For example, a shortage index of 0.01 would generally involve less than four annual shortages.

YIELD-STORAGE METHODOLOGY

Storage-yield relationships, which describe the amount of flow (yield or draft) which can be maintained under various assumptions of storage and risk criteria (shortage index), were developed for all the incremental drainage areas, and also some total river basin areas, by means of a computer program originating in the Baltimore District, Corps of Engineers, and modified for the purposes of this study in the NAR Study Group.

The yield-storage program takes the monthly streamflow data, extended to the length of the longest station in each group, in the case of historic records, and the ten 100-year synthetic traces, and by subtraction, where necessary, determines incremental area inflows. Then, by assuming hypothetical storage amounts, the record in each area is tested for sufficiency in maintaining pre-set requirements in terms of percentages of the average flow. Deficiencies are expressed in terms of shortage index.

The input to the yield-storage program is historic and synthetic monthly streamflow data for each group of stations. As was previously discussed, the historic records were extended to the length of the longest station in each group in the simulation analyses and ten 100-year synthetic traces were generated for each station. In the yield-storage program, the historic, and each of the synthetic traces, is analyzed separately.

The first step of the program is to determine, by subtraction of flows, the input to those areas lying between successive stream gages. The local area inflows thus determined are assumed to be comparable to the flows at individual gages for the purposes of deriving yield-storage relationships.

The program simulates the operation of a reservoir at the outlet of each of the areas by applying each month's streamflow to the equation:

$$S_i = S_{ti} + I - 0$$

In which:

S_i = the storage at the end of month i

S_{ti} = the storage at the end of the previous month

I = the average inflow for month i

O = the average outflow for month i

If Si is negative, the hypothetical reservoir has been emptied and a shortage is said to exist. From this point, the shortage will continue as long as O exceeds I. It remains to evaluate the magnitude and duration of each shortage under various assumed requirements of outflow (yield) and risk (shortage index).

The draft rates selected for analysis in the program were 20%, 40%, 50%, 60%, 70%, 80% and 90% of the average flow. Provision was made in the program for a monthly variation in demand and Table C-12 indicates the monthly variation selected for these analyses. This table is based on observed average seasonal variability requirements and is considered to be representative of both normal and dry years.

TABLE C-12
RATIO OF MONTHLY DEMAND TO AVERAGE ANNUAL DEMAND

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
95%	95%	95%	95%	100%	110%	110%	110%	105%	95%	95%	95%

All draft rates are initially routed at zero storage. The second routing sequence begins with an assumed storage dependent upon the size of drainage area and draft rate. In Case I, where one inch of storage over the drainage area is equivalent to less than 100,000 acre-feet, the storage for the second routing sequence is set equal to one-half inch at the 20% draft rate, one inch at 40% and 50%, two inches at 60% 70% and 80%, and three inches at 90%. In Case II, where one inch of storage is between 100,000 and 200,000 acre-feet, the second routing sequence storage assumption is 50,000 acre-feet at the 20% draft rate, 100,000 acre-feet at 40% and 50%, 200,000 acre-feet at 60%, 70% and 80%, and 300,000 acre-feet at 90%. In Case III, where one inch is greater than 200,000 acre-feet, the second sequence is 100,000 acre-feet at 20%, 200,000 acre-feet at 40% and 50%, 400,000 acre-feet at 60%, 70% and 80%, and 600,000 acre-feet at 90%.

Storage increments are added after the second routing sequence until one or no failures occur. Where the number of failure months is less than 75, increments equivalent to the initial storage assumption are applied. When the number of failures is greater than 75, the following increments are applied: one inch at 20%, two inches at 40% and 50%; three inches at 60%, four inches at 70% and 80%, and five inches at 90%, in Case I; 100,000 acre-feet at 20%, 200,000 acre-feet at 40% and 50%, 300,000 acre-feet at 60%, 400,000 acre-feet at 70% and 80%, and 500,000 acre-feet at 90%, in Case II; and 200,000 acre-feet at 20%, 400,000 acre-feet at 40% and 50%, 600,000 acre-feet at 60%, 800,000 acre-feet at 70% and 80%, and 1,000,000 acre-feet at 90%, in Case III.

The program provides for setting the initial condition of the hypothetical reservoir prior to each routing, and it was assumed for these analyses that the reservoir would contain one-quarter of the assumed storages prior to testing each run.

The program output was plotted as shown on Figure C-9 to show the storage requirements at different shortage indices for the various demand rates. This sample was plotted from the output format, an example of which is shown in Table C-13. Storages listed in Column 1 of the Table were converted to acre-feet per square mile and plotted against the corresponding shortage index shown in Column 17. The data in Column 2 represents percentages of average flow; the first set representing 20%, the second 40%, the third 50%, and increasing by intervals of 10 up to 90%. The average flow used in all cases was the long-term average of the historic record, since the model used to generate synthetic streamflow traces preserves the mean to within a fraction of a percent. The family of generated curves shown on Figure C-9 is represented by the average of the 10 shortage indices (one for each 100-year period) at each assumed storage value and draft rate. The average was used to avoid bias by the 1,000-year low flow occurrence, far beyond the project life of any reservoir, and to avoid placing particular emphasis on one 100-year trace, since any of the 10 traces should be as likely to occur as a recurrence of the historic record.

The figure in parentheses below the storage requirement at 1 or zero failures for each draft rate in Table C-13 represents the storage surplus (negative) at zero failures or the storage deficiency (positive) at 1 failure. That is, the exact storage needed for a shortage index of 0 can be obtained by subtracting the surplus from the last storage requirement in the case of zero failures or adding the deficiency to the final requirement in the case of one failure.

The number of failures shown in Column 3 represents the sum total of failure - months, shown in Columns 4 thru 15. For example, the 13 failures of two-month consecutive length equals 26 failure - months. The average spillage, in Column 16, represents the amount of water wasted at the given storage requirement when the hypothetical reservoir is full. Column 18 gives the amount of water in storage at a selected month of the final year of the routing sequence. Columns 19 through 22 show the largest single monthly shortage and the average of all monthly shortages, for each routing, in both c.f.s., and percent of the draft rate being routed as outflow.

In the processing of local areas where the flow from the

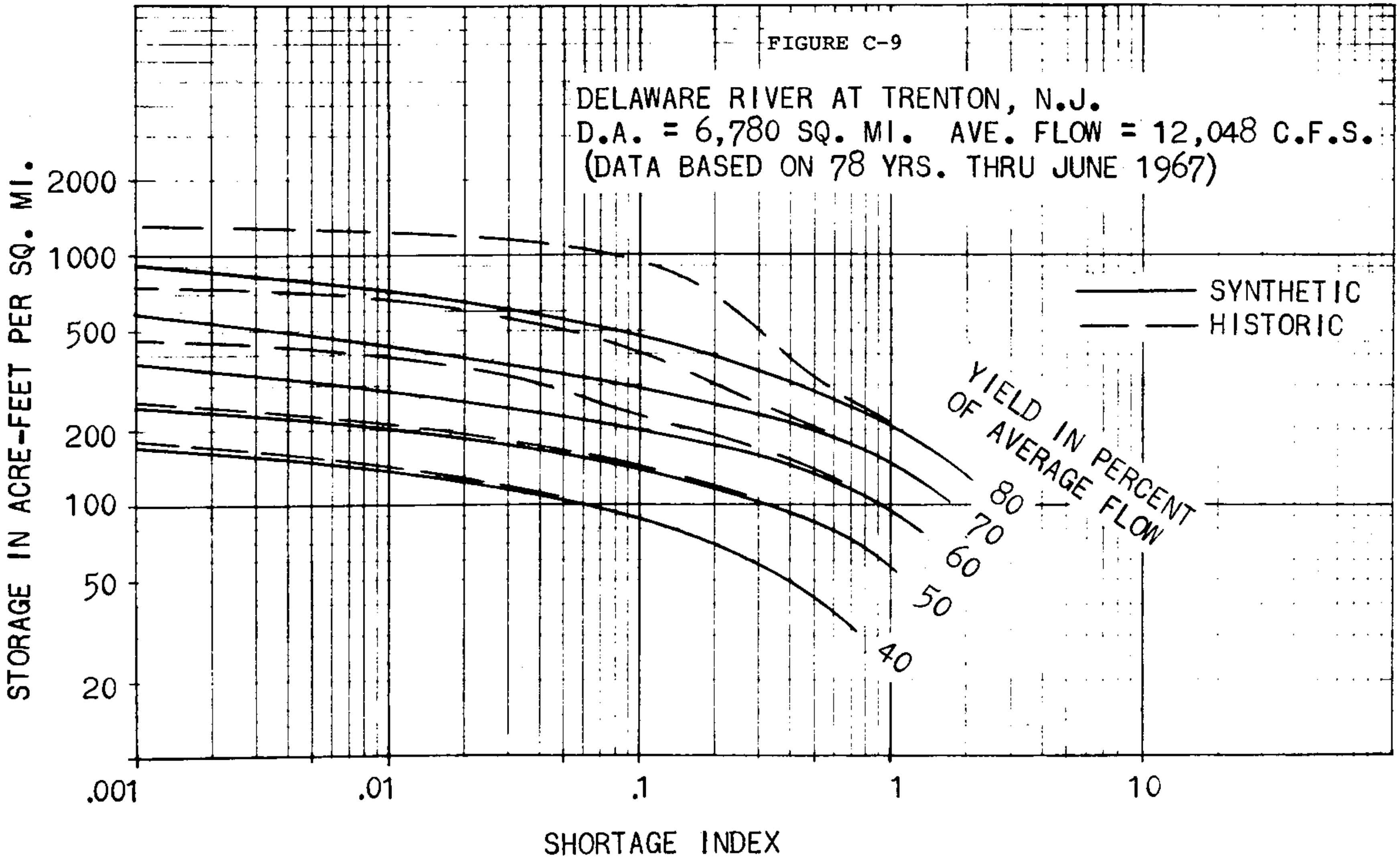


FIGURE C-9
DELAWARE RIVER AT TRENTON, N.J.
D.A. = 6,780 SQ. MI. AVE. FLOW = 12,048 C.F.S.
(DATA BASED ON 78 YRS. THRU JUNE 1967)
SYNTHETIC
HISTORIC
YIELD IN PERCENT OF AVERAGE FLOW
80
70
60
50
40
STORAGE IN ACRE-FEET PER SQ. MI.
2000
1000
500
200
100
50
20
.001
.01
.1
1
10
SHORTAGE INDEX

TABLE C-13
SAMPLE OUTPUT OF YIELD-STORAGE RESULTS

*****/ANALYSIS/OF/YIELD/AT/STATION*****
451 WEST BRANCH DELAWARE RIVER AT HALE EDDY.NY. DA 593

BASED ON 69 YEARS OF ACTUAL OR PARTIALLY ESTIMATED RECORD

STORAGE ACFT (DEFICIENCY)	AVG DRAFT CFS	NUMBER OF FAILURES	NUMBER OF FAILURES OF CONSECUTIVE MONTH LENGTH 1	2	3	4	5	6	7	8	9	10	11	12+	AVG ANNUAL SPILLAGE CFS	SHORTAGE INDEX	FINAL STORAGE ACFT	FAILURES 1ST IN CFS	AVG IN CFS	1ST IN PCT	AVG IN PCT
0	207	145	28	13	7	13	1	1	1	0	0	0	0	0	842	1.12183	0	202	89	90	41
15813	207	39	3	8	4	2	0	0	0	0	0	0	0	0	830	.21268	15813	176	88	82	42
31627	207	4	0	2	0	0	0	0	0	0	0	0	0	0	826	.01946	31627	155	86	80	44
47440	207	1	1	0	0	0	0	0	0	0	0	0	0	0	826	.00010	47440	21	21	11	11
(1251)																					
0	414	268	28	14	11	15	6	10	3	1	0	0	0	0	691	3.90178	0	430	217	95	51
31627	414	128	10	9	13	7	4	1	1	0	0	0	0	0	651	1.28405	31627	398	204	88	49
94880	414	10	3	0	1	1	0	0	0	0	0	0	0	0	621	.02903	94880	352	140	90	36
126507	414	3	1	1	0	0	0	0	0	0	0	0	0	0	619	.00010	126507	23	19	6	5
158133	414	0	0	0	0	0	0	0	0	0	0	0	0	0	618	0.00000	158133	0	0	0	0
(-29508)																					
0	517	314	28	17	14	9	14	10	4	2	0	0	0	0	627	5.54508	0	543	286	96	53
31627	517	176	9	12	9	14	8	1	2	0	0	0	0	0	578	2.50500	31627	532	293	94	55
94880	517	51	7	8	6	0	2	0	0	0	0	0	0	0	530	.28399	94880	455	223	93	45
126507	517	19	7	2	0	2	0	0	0	0	0	0	0	0	520	.04869	126507	450	155	92	32
158133	517	7	0	2	1	0	0	0	0	0	0	0	0	0	517	.01008	158133	214	127	44	26
189760	517	1	1	0	0	0	0	0	0	0	0	0	0	0	515	.00006	189760	41	41	9	9
(2501)																					
0	620	362	40	14	18	10	8	15	6	0	2	1	0	0	567	7.25494	0	657	348	97	54
63253	620	162	10	9	12	13	5	0	3	0	0	0	0	0	476	2.03940	63253	633	326	93	52
158133	620	30	8	4	0	2	0	1	0	0	0	0	0	0	421	.12944	158133	553	217	85	37
221387	620	10	0	2	0	0	0	1	0	0	0	0	0	0	415	.05614	221387	553	183	85	30
284640	620	5	0	0	0	0	1	0	0	0	0	0	0	0	412	.00556	284640	312	105	53	18
347893	620	0	0	0	0	0	0	0	0	0	0	0	0	0	411	0.00000	347893	0	0	0	0
(-31240)																					
0	724	404	39	18	16	14	10	14	9	0	2	1	0	0	516	9.04839	0	770	413	97	55
63253	724	208	17	13	12	12	12	0	3	0	0	0	0	0	413	3.31846	63253	746	412	94	56
189760	724	38	9	7	0	2	0	0	1	0	0	0	0	0	324	.26587	189760	712	308	90	45
253013	724	12	0	1	1	0	0	0	1	0	0	0	0	0	315	.15328	241305	712	335	90	47
316267	724	6	0	0	0	0	0	1	0	0	0	0	0	0	313	.07926	241305	664	365	84	50
379520	724	5	0	0	0	0	1	0	0	0	0	0	0	0	312	.01913	241305	410	230	60	33
442773	724	1	1	0	0	0	0	0	0	0	0	0	0	0	311	.00024	241305	112	112	17	17
(6804)																					
0	827	433	40	16	16	12	11	18	8	1	2	2	0	0	463	10.80498	0	884	488	98	57
63253	827	263	14	13	13	13	15	4	0	3	1	0	0	0	356	4.73442	63253	884	473	98	56
189760	827	79	5	13	8	0	2	1	0	1	0	0	0	0	244	.71895	189760	884	388	98	49
316267	827	20	0	3	2	0	0	0	0	1	0	0	0	0	217	.27894	196485	884	392	98	48
379520	827	12	0	1	1	0	0	0	1	0	0	0	0	0	214	.19497	196485	826	448	91	54
442773	827	11	0	1	1	0	0	1	0	0	0	0	0	0	213	.10880	196485	770	394	89	49
506027	827	10	0	1	1	0	1	0	0	0	0	0	0	0	213	.05449	196485	513	330	66	42
569280	827	8	0	1	2	0	0	0	0	0	0	0	0	0	212	.03204	196485	513	282	66	36
632533	827	4	0	2	0	0	0	0	0	0	0	0	0	0	211	.01299	196485	513	304	66	39
695787	827	1	1	0	0	0	0	0	0	0	0	0	0	0	210	.00046	238991	176	176	23	23
(10706)																					
0	930	469	41	18	12	12	12	19	10	2	2	3	0	0	417	12.57676	0	998	553	98	58

TABLE C-14
COMPARISON OF AVERAGE FLOW
Recorded and Reconstituted Flow vs. Generated Flow
(c.f.s.)

STATION NUMBER	Rec. & REC.	Generated Period Number 1	2	3	4	5	6	7	8	9	10
378	7,356	7,363	7,381	7,366	7,368	7,355	7,381	7,397	7,364	7,378	7,374
605	7,048	7,064	7,111	7,100	7,136	7,069	7,071	7,065	7,089	7,114	7,106
623	9,261	9,384	9,292	9,339	9,306	9,404	9,258	9,251	9,292	9,288	9,333
519	33,935	33,987	34,181	34,089	34,162	33,119	33,989	34,091	34,182	34,098	34,032
479	12,138	12,064	12,318	12,167	12,197	12,186	12,088	12,143	12,162	12,096	12,117
259	13,714	13,719	13,739	13,689	13,754	13,719	13,761	13,770	13,754	13,697	13,726
275	7,363	7,367	7,401	7,358	7,418	7,356	7,393	7,379	7,398	7,347	7,345
153	6,071	6,054	6,088	6,049	6,081	6,092	6,092	6,071	6,094	6,041	6,075
162	11,710	11,714	11,718	11,734	11,719	11,720	11,717	11,679	11,698	11,719	11,744
118	9,637	9,677	9,605	9,594	9,604	9,591	9,586	9,574	9,644	9,556	9,598

upstream station or stations were subtracted from the flows at the downstream station, some negative flows resulted due to timing differences in observations. In cases where these negatives were obtained they were set to zero before starting the routing interval. The number of negative flows set equal to zero is indicated in the printout for local areas.

As previously stated, the storage at the beginning of each routing interval was set at 25% of the assumed storage (Column 1 of Table C-13). That is, the reservoir is one-quarter full when the routing period begins. This was assumed arbitrarily, since any condition could prevail at the beginning of operations at any particular site, and timing and scope of analyses did not permit varying the assumption over a wide range of values. In several instances, large storage requirements resulted from critical drought conditions during the initial years of a generated streamflow trace. The average curves were manually smoothed in then cases, under the assumption that full yield would not normally be required during the initial years of operation. It should be noted that initial volume assumptions can affect results and should be analyzed in light of the specific requirements of detailed studies.

DISCUSSION OF RESULTS

The curves based on the actual and partially estimated record are shown as dotted lines on Figure C-9. The solid lines represent the average of the ten-100 year generated traces. At this station the severity of the 1960s drought is vividly indicated by the steep slope of the dotted lines for yields of 70% and 80% of the average flow at a shortage index of about 0.2. Because of the extended deficiencies during this drought, a substantial amount of storage would be necessary to provide enough annual carryover to maintain these yields through the latter years of the drought. For purposes of comparison, a separate trial was made, using both the simulation and the yield-storage programs, in which the records of the latest drought were excluded. Figure C-10 shows these results. In terms of the historic data, there is a marked reduction in storage requirements for a given yield and shortage index. However, it is interesting to note that the curves based on the synthetic records are relatively stable, even though 10 fresh sequences were generated and the amount of input data used was considerably less.

The relationships between historic and synthetic storage requirements showns in the last two figures are not typical of all areas in NAR. It was found that in many areas, the historic data produced a smooth, stable family of curves. And, on occasion, a synthetic trace was found to contain a severe drought similar to that which affects the historic requirements in Figure C-9.

In an attempt to uncover any regional patterns between storage requirements based on the historic record, and those based on the synthetic records, a tabulation of storage values at 50% average flow and a

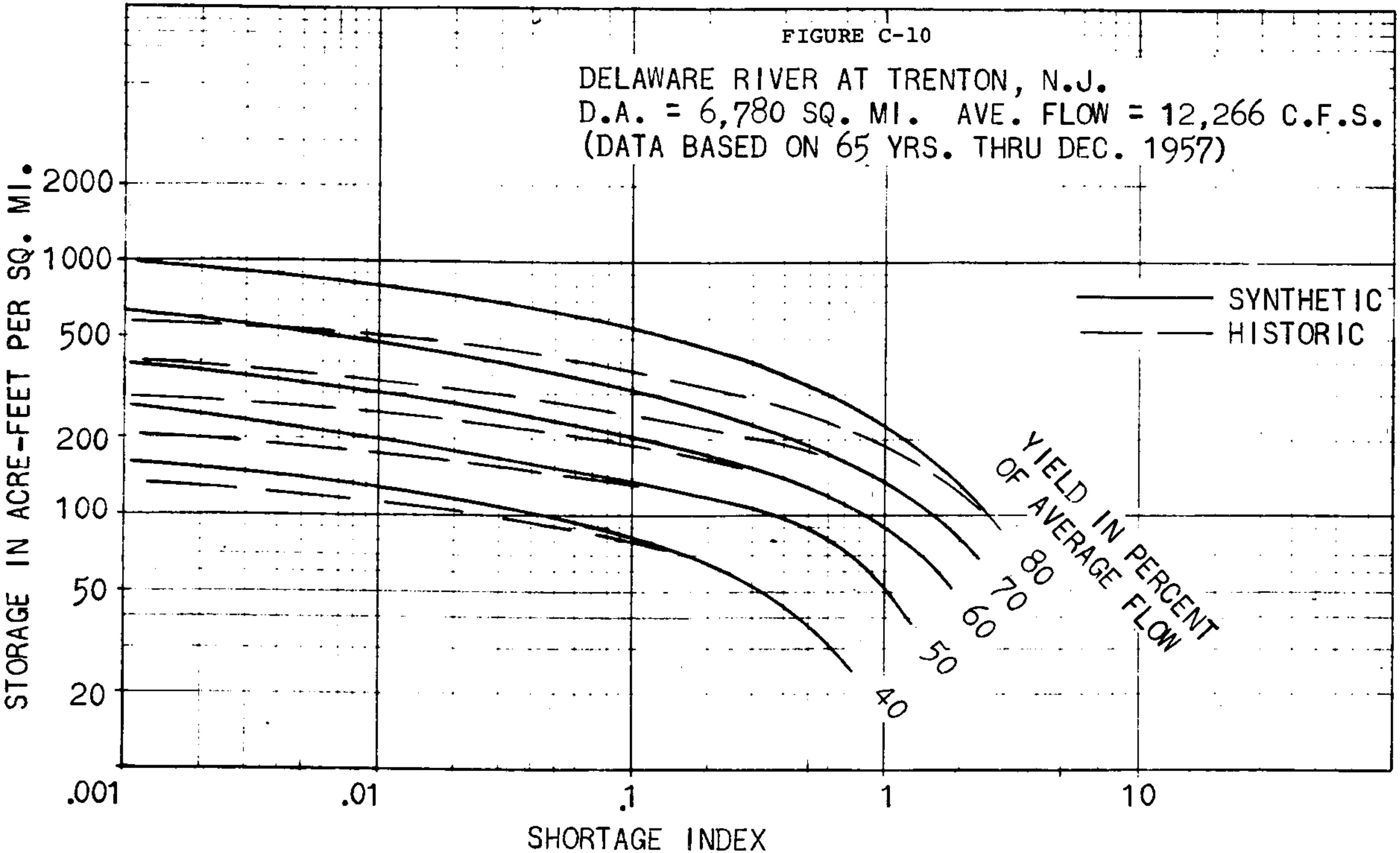


FIGURE C-10
DELAWARE RIVER AT TRENTON, N.J.
D.A. = 6,780 SQ. MI. AVE. FLOW = 12,266 C.F.S.
(DATA BASED ON 65 YRS. THRU DEC. 1957)
SYNTHETIC
HISTORIC
YIELD IN PERCENT OF AVERAGE FLOW
80
70
60
50
40
STORAGE IN ACRE-FEET PER SQ. MI.
2000
1000
500
200
100
50
20
.001
.01
.1
1
10
SHORTAGE INDEX

median shortage index of 0.05 was made for all areas, and the ratio between the historic and synthetic storage values determined. Figure C-11 indicates the results of this study. In a large portion of the NAR the difference is within 10%, and in a few scattered areas, the historic requirement is significantly less than that based on the synthetic average. In southwestern New England, New York State in Sub-region C, the mid-section of Sub-region D, portions of the Potomac River Basin, and the Rappahannock and lower James River Basins, the historic value is significantly greater than the synthetic average. If the recent drought was as severe as generally believed, areas such as these, with an historic storage requirement significantly greater than the synthetic average requirement, should be possible. Also, it is possible that other droughts of record, such as the one in the early 1930s, could be of this order of severity in some areas. It was noted that in many areas where the historic storage requirement was the more critical, the recent drought was particularly severe. In 1964 and 1965, extreme conditions prevailed in southwestern New England, large areas in Sub-region C, the Delaware Basin particularly in New Jersey, and the lower James River Basin.

Yield-storage results for the key stations and local areas are presented in tables in the Sub-regional Summaries. Typical graphic representations are also included. Results from both the historic and synthetically generated records are given for selected shortage indices.

Some further general conclusions can be made from the yield-storage results. Table C-15 summarizing storage requirements by Sub-region for comparative purposes was derived by averaging the data presented in each Sub-regional Summary.

TABLE C-15
COMPARISON OF HISTORIC AND SYNTHETIC STORAGE REQUIREMENTS
SHORTAGE INDEX = 0.01
(Figures in acre-feet per square mile)

	YIELD = 60% OF AVERAGE FLOW		YIELD = 80% OF AVERAGE FLOW	
	Historic	Synthetic	Historic	Synthetic
Sub-region A	344	406	763	1,034
Sub-region B	455	352	1,066	1,020
Sub-region C	308	263	699	695
Sub-region D	377	337	1,143	1,050
Sub-region E	354	352	900	920
Sub-region F	286	268	660	772
TOTAL NAR	354	330	862	902

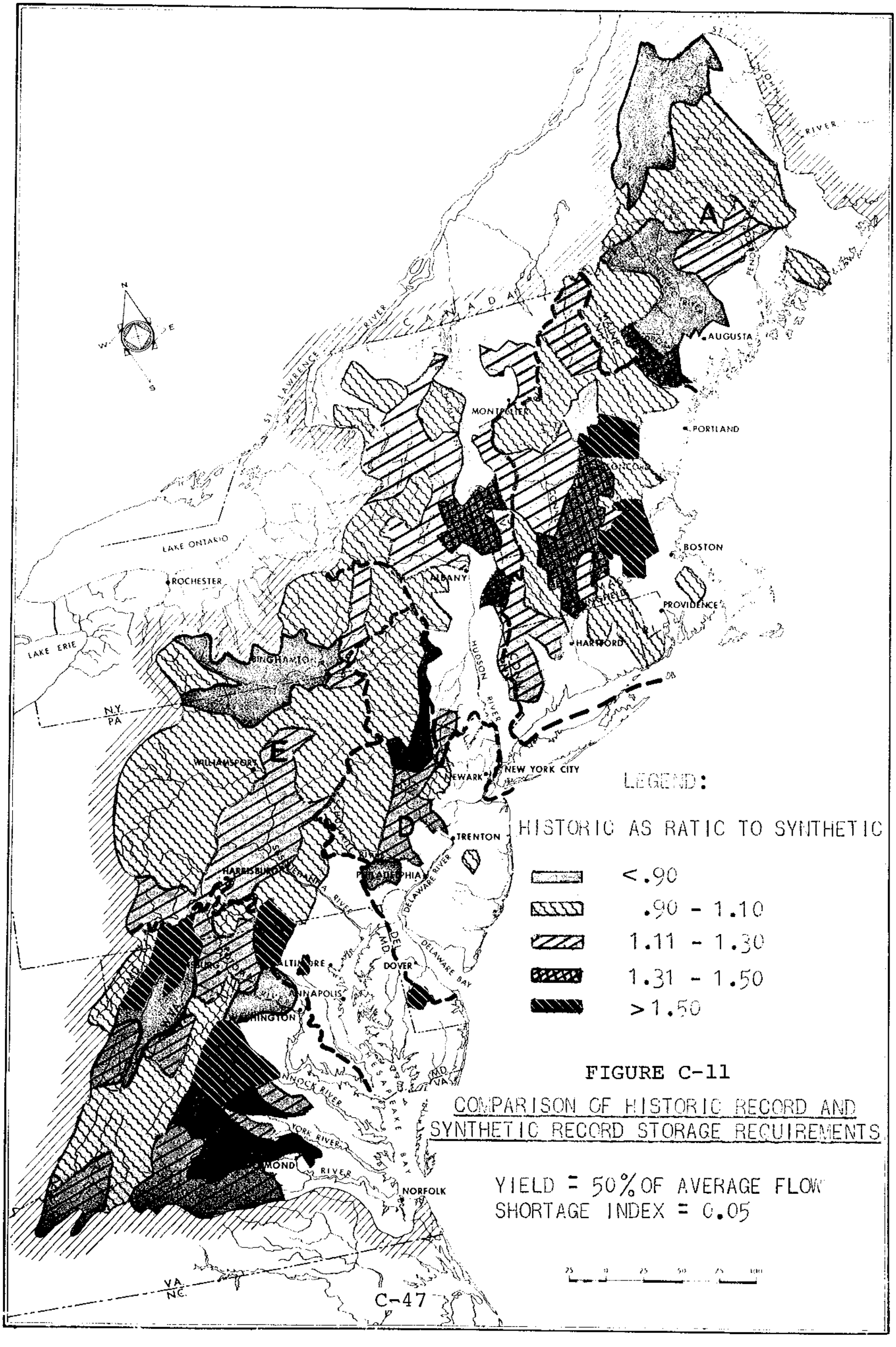


FIGURE C-11

COMPARISON OF HISTORIC RECORD AND SYNTHETIC RECORD STORAGE REQUIREMENTS

The Table shows that on a Regional average-basis, storage requirements based on the historic and synthetically generated records are not very different. However, on a Sub-regional basis, the historic requirement varies from 85% of synthetic in Sub-region A to almost 130% in Sub-region B for a yield of 60% of average flow. The greater historic storage requirement in Sub-regions B, C, D and, to a lesser extent, F, reflect unusual severity in historic drought events.

At a yield of 80% of average flow, the historic requirement for Sub-region D is still significantly greater than the requirement derived from the synthetic records. This is consistent with the relatively long and severe shortages which occurred during the drought of the 1960s throughout most of this Sub-region.

It should be recognized that conditions within a Sub-region can vary significantly from the average, and the data for individual areas as shown in the storage requirements tables in the Sub-regional Summaries should be used as the basis for yield estimates. Even here it is noted that the areas analyzed are rather large, and even though yield-storage relationships tend to be independent of area size, extrapolation to much smaller areas may yield inconsistent results.

In view of the current state of the development of techniques for generation of simulated monthly streamflow traces, the stability of the results of the analyses of synthetic records, and the reasonableness of these results in the light of recent occurrences and their apparent perspective in history, it was decided to adopt the results of the yield-storage analyses of synthetically generated records for use in this Type I Study. The results of comparable analyses of the historic records are also available and are presented, in part, in the Sub-regional Summaries.

ADOPTED SHORTAGE INDEX

It was considered that a criterion of zero shortage index would be inappropriate for the study. This criterion is believed unreasonable in that storage requirements would then be related to the length of the synthetic (or historic) record used since longer records tend to include more severe droughts. Also, it was felt that some shortages could be tolerated, even in municipal and industrial water supply, by curtailment of less important uses.

A shortage index of 0.01 was adopted for general use in connection with withdrawal needs in the Study. This is a relatively severe measure and was selected on the basis that a large portion of these needs would be related to public water supply. Under the adopted criterion theoretical shortages, such as the following examples, would be permissable in 100 years: one 10% annual (40% three-month) shortage; or, two 7% annual (28% three-month) shortages; or, five 4.5% annual (18% three-month) shortages; or, a combination of one 7% annual (28% three-month) shortage and three 4% annual (12% three-month) shortages. The adopted shortage index of 0.01 will lead to storage requirements that will be about equivalent to those that would be obtained by frequency analyses methods with risk levels ranging from 1 to 2 percent.

It should be noted that the above equivalent three-month shortages imply situations more severe than are likely, since, in most cases, forecasting and operating techniques would be developed to mollify infrequent short-duration occurrences by substituting somewhat longer deficiences of reduced severity.

COMPARISON OF CRITERIA

The difference between the amount of storage required to maintain a designated flow at no shortage tolerance and at a tolerance equivalent to a shortage index of 0.01 for individual areas can be seen in the storage requirement tables in the Sub-regional Summaries. In order to show a general quantitative relationship between the two, the storage requirement at S.I. 0.01 for both historic and synthetic traces at a development equivalent to 60% of average flow was divided into the historic requirement at S.I. 0.0 for each area. It is noted that this degree of development corresponds closely to the average development of the potential major river sites covered in Appendix E. Results show that when the historic record only is considered, the amount of storage required at S.I. 0.0 would be about 18% greater than the storage required at S.I. 0.01 for the Region as a whole. Or, if the same storage as that required at S.I. 0.01 were used to obtain the "no-failure" criteria (S.I. 0.0), about 7% less yield would be provided.

As indicated in Table C-16, a comparison of results using synthetic records (S.I. 0.01) and the historic record (S.I. 0.0) results in a storage difference for the entire Region of 26%. For the S.I. 0.01 storage, the yield reduction (10%) is also somewhat greater. It is noted that in Sub-region A, where the storage requirement for the synthetic record is generally greater than the historic for a given shortage index, there would be practically no difference between historic S.I. 0.0 and synthetic S.I. 0.01. In Sub-region B, where the synthetic storage required is usually less than the historic for a given index, about 48% more storage would be required under historic no-risk criterion to provide a yield of 60% of the average flow.

TABLE C-16
COMPARISON OF STORAGE AND YIELD RESULTS FROM HISTORIC AND SYNTHETIC RECORDS FOR SHORTAGE INDICES OF 0.0 AND 0.01

	RATIO OF STORAGE REQUIREMENTS FOR YIELD OF 60% AVERAGE FLOW		RATIO OF YIELDS BASED ON SI 0.01 STORAGE REQUIRED FOR 60% OF AVERAGE FLOW	
	Historic (S.I. = 0.0) / Historic (S.I. = 0.01)	Historic (S.I. = 0.0) / Synthetic (S.I. = 0.01)	Historic (S.I. = 0.0) / Historic (S.I. = 0.01)	Historic (S.I. = 0.0) / Synthetic (S.I. = 0.01)
Sub-region A	1.17	0.99	.93	1.00
Sub-region B	1.14	1.48	.95	.88
Sub-region C	1.20	1.41	.92	.87
Sub-region D	1.22	1.37	.95	.90
Sub-region E	1.16	1.16	.93	.87
Sub-region F	1.17	1.25	.93	.90
NAR	1.18	1.26	.93	.90

ANALYSIS OF WATER AVAILABILITY - UPSTREAM STORAGE

Generalized relationships between yield and storage in upstream areas were derived by the Soil Conservation Service, U.S. Department of Agriculture in connection with studies for Appendix F, Upstream Flood Prevention of Water Management. The purpose of the analysis was to develop a practical upper limit of water storage for beneficial use other than flood control.

YIELD-STORAGE METHODOLOGY

A computer program developed by the Soil Conservation Service at Hyattsville, Md., was utilized. Input data included monthly runoff in inches which was compared with the desired draft rate or yield by the program. Amounts of shortages were accumulated in order to determine the maximum deficiency during each low flow period in the imput record. These deficiencies were converted into storage requirements in inches and percent of average annual runoff which were listed as the program output for each draft rate at a given stream gage station. Draft rates of 10%, 20%, 30%, 40%, 50%, 60%, 70% and 80% of the average annual runoff were used.

Storage requirements were ordered for each draft rate and assigned plotting positions using the formula:

$$Fa = \frac{100\ (2n-1)}{2y}$$

in which:

Fa = the plotting position in percent,

n = the rank number, and

y = the number of shortage events.

Smooth curves were drawn of probability versus storage for each draft rate. This data were then used to develop a family of curves at each station relating draft rate to storage for various probabilities. Figure C-12 is an example showing the curves developed for Ayers Brook at Randolph, Vt. Average annual runoff used in these analyses was taken from Hydrologic Investigations Atlas HA-212 by Mark W. Busby, published by the U.S. Geological Survey (See Figure C-5, p. C-14).

The maximum possible draft rate is about 100% of average annual runoff. Due largely to economic factors the maximum practical continuous draft rate is considered to be approximately 80% of the average runoff. This draft rate was adopted subject to limitations of topography or excessive cost for land easements and rights of ways in individual cases. A 1% chance of shortage was adopted as being consistent with established criteria for this type of development, considering the possible use of beneficial storage for a variety of purposes including rural domestic, municipal and industrial water supply.

Analyses were made for 24 stream gages in the North Atlantic Region with drainage areas varying from 4 to 173 square miles and average annual runoff between 12 and 34 inches (See Table C-17). Records were available through Water Year 1964 at most stations at the time of these analyses.

There is no direct conversion from the frequency method used by the Soil Conservation Service to the shortage index evaluation of risk used in other parts of this appendix. A 1, 5 or 10 percent chance of shortage could be equal to a shortage index of 0.01 if the 1 shortage in a 100 years is 10% below expected draft or the 5 and 10 shortages 5 percent or 3 percent, respectively. In general a 2 percent chance of shortage approximates the same degree of risk as a Shortage Index of 0.01. In some location however S.I. 0.01 is somewhat more stringent.

GENERALIZED RESULTS

The draft-storage-probability curves constructed for these stations

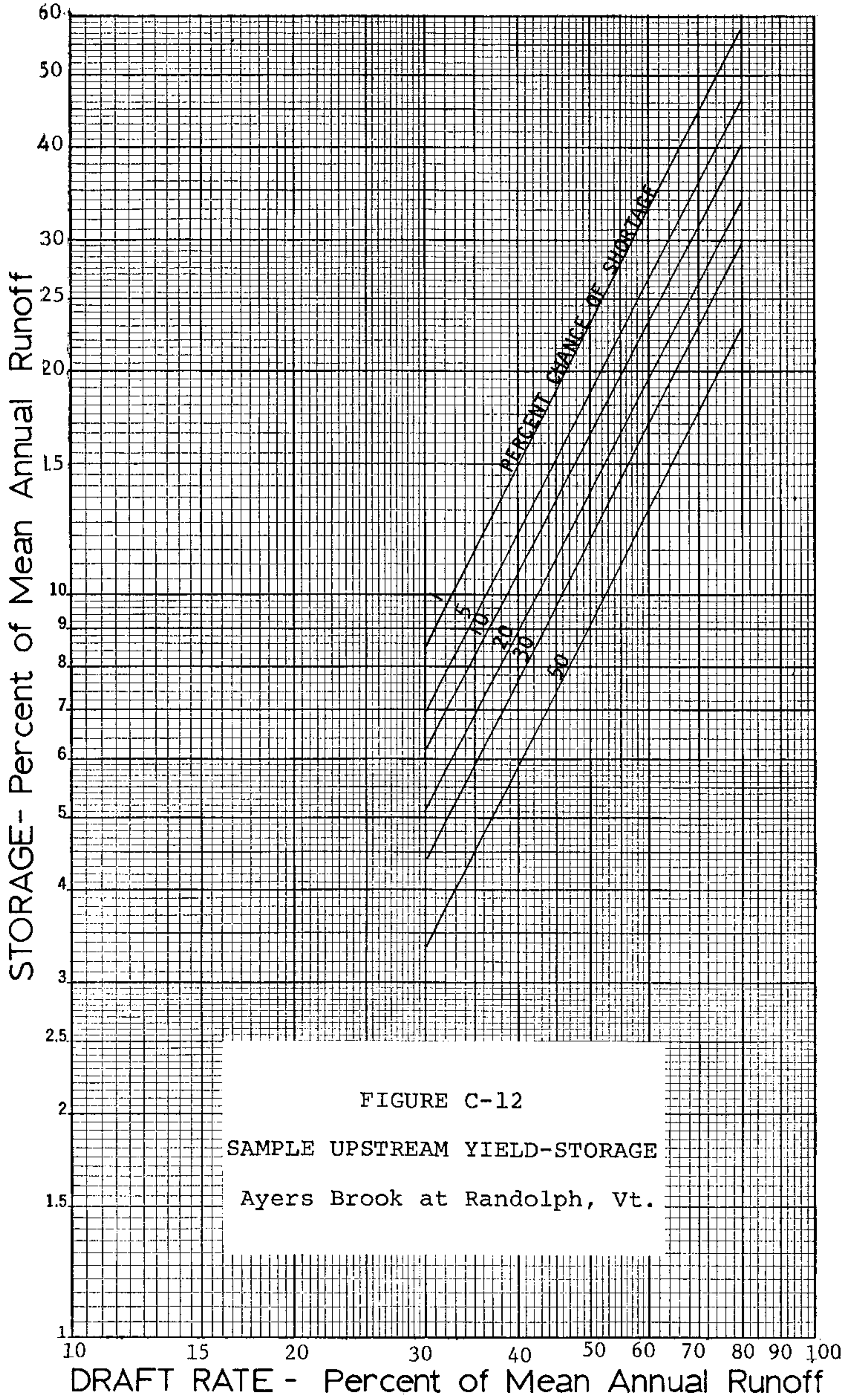


FIGURE C-12

SAMPLE UPSTREAM YIELD-STORAGE

Ayers Brook at Randolph, Vt.

TABLE C-17
UPSTREAM CONTROL STATIONS

Station	Average Annual Runoff-in.	Drainage Area Sq. Mi.	Record Yrs.[1/]
Austin Stream at Bingham, Me.	26.11	90.3	33
Little Androscoggin R. nr. So. Paris, Me.	23.89	76.2	33
Ayers Brook at Randolph, Vt.	20.00	30.5	25
Williams R. at Brockways Mills, Vt.	21.60	103	24
No. Branch Hoosic R. at No. Adams, Mass.	33.96	39.0	33
Mt. Hope R. nr. Warrenville, Conn.	23.46	27.8	24
E. Br. Eightmile R. nr. N. Lyme, Conn.	27.76	22.0	47
Beaver Kill at Craigie Clair, N. Y.	32.43	82	27
Moshannon Creek at Osceola Mills, Pa.	21.92	68.8	24
Manasquan R. at Squankum, N. J.	22.51	43.4	33
Oswego R. at Harrisville, N.J.	18.52	64.0	35(1965)
Schuylkill R. at Pottsville, Pa.	26.96	53.4	21
Assunpink Creek at Trenton, N. J.	18.03	89.4	41
Stockley Branch at Stockley, Del.	19.15	5.24	17(1960)
Beaverdam Cr. nr. Salisbury, Md.	17.35	19.5	22(1960)
Monocacy R. at Bridgeport, Md.	15.40	173	18(1960)

TABLE C-17 CONT.
UPSTREAM CONTROL STATIONS

Station	Average Annual Runoff-in.	Drainage Area Sq. Mi.	Record Yrs. 1/
Owens Cr. nr. Lantz, Md.	20.65	5.93	29(1960)
Mountain Run nr. Culpeper, Va.	13.92	14.7	15
North R. nr. Stokesville, Va.	15.03	23.4	18
Hudson Cr. nr. Boswells Tavern, Va.	14.98	4.1	16
Totopotomoy Cr. nr. Atlee, Va.	13.84	6.0	16
Kerrs Cr. nr. Lexington, Va.	14.83	34	38
Deep Cr. nr. Mannboro, Va.	12.08	156	18
Buffalo Cr. nr. Hampden-Sydney, Va.	12.60	70	18

1/ Record years run through 1964 unless otherwise indicated in parentheses.

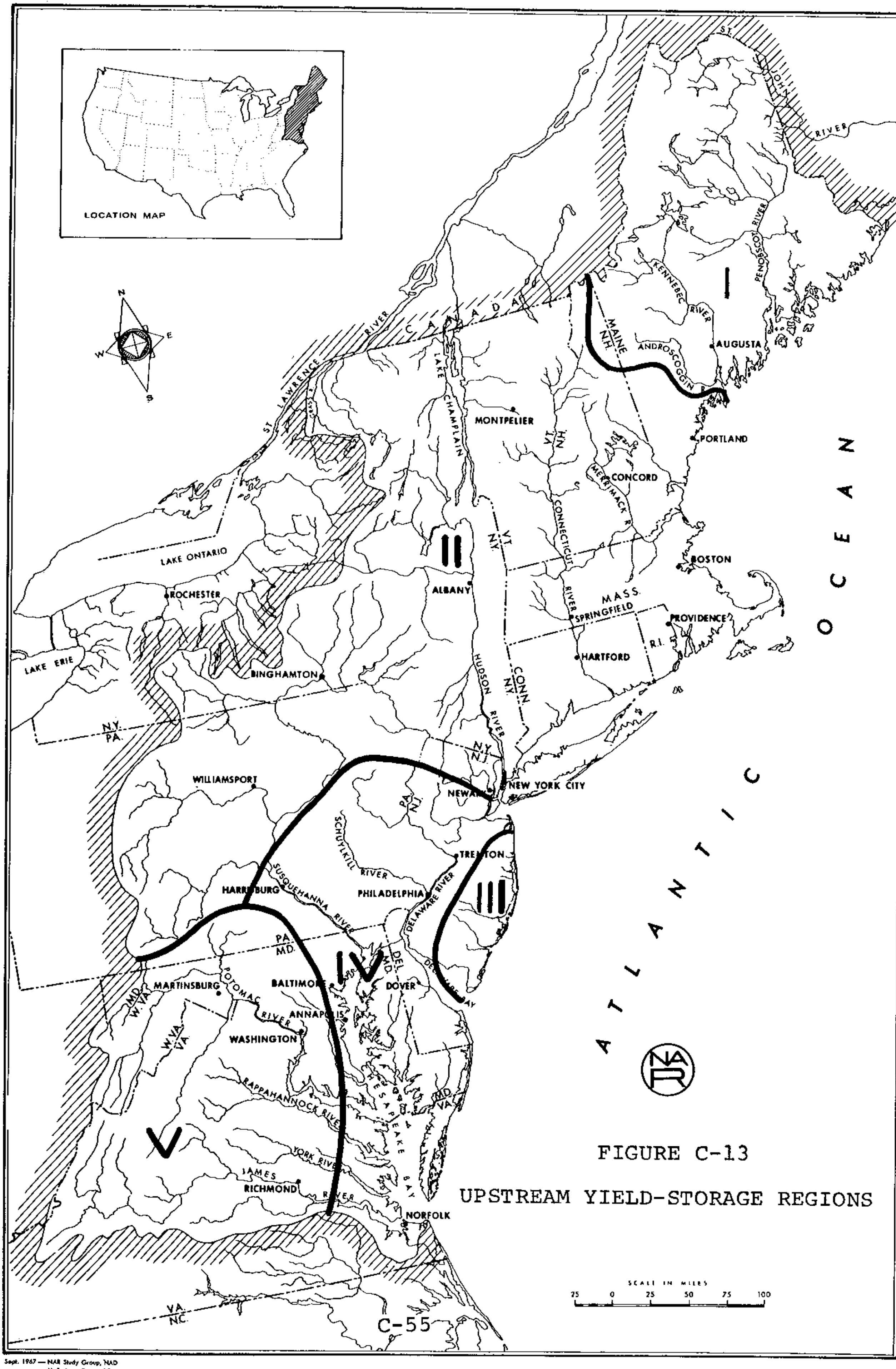


FIGURE C-13

UPSTREAM YIELD-STORAGE REGIONS

were compared and grouped into regions having approximately the same storage requirements for an 80% draft rate and a 1% change of shortage. The results of this generalization are given in Table C-18 and the regions are delineated on Figure C-13.

TABLE C-18
UPSTREAM GENERALIZATIONS - RESERVOIR STORAGE REQUIREMENTS
(1% change of shortage, 80% draft rate)

REGION 1/	STORAGE REQUIRED-IN TERMS OF AVERAGE ANNUAL RUNOFF
I	75%
II	55%
III	40%
IV	65%
V	90%

1/ Soil Conservation Service upstream yield-storage regions, which are shown in Figure C-13, p.

ANALYSIS OF MINIMUM FLOWS

A study of minimum flows was made in connection with the development of the existing resource in the 21 NAR planning Areas (See Appendix E). Results are given by Sub-region, Area and Sub-area in the Sub-regional Summaries.

METHODOLOGY

The first step in this analysis was the determination of that monthly flow that could be accepted as a minimum safe flow with a shortage index of 0.01. In other words the monthly flow determined as the minimum for this analysis is a flow that for instance can be expected 99 times in a 100 years with one year 10% lower than the minimum, or 98 times in a 100 years with the two shortages being not greater than 7%. Each of these minimums were first approximated by inspection of the record and then refined by successive approximations.

For each monthly flow with a shortage index of 0.01, an estimate was made of the approximate seven-day flow. This was accomplished by studying the daily flow records for low flow months at the stations involved and adopting a percentage which would yield the approximate seven-day flow corresponding to the calculated monthly flow. Adopted percentages varied from about 50% to 90%, depending upon the flow characteristics of the individual rivers, particularly the degree of existing regulation, but did not vary greatly for similar streams.

RESULTS

It was found that low flows based on the adopted percentages of monthly flow with shortage index of 0.01 were close to seven-day, 50-year flows determined in previously completed studies by others.

TABLE C-19
COMPARISON OF SEVEN-DAY MINIMUM FLOWS
(Drainage areas in square miles, flows in average c.f.s.)

STATION	NAR AREA	DRAINAGE AREA	NAR FLOW	OTHER STUDIES 1/ FLOW	SOURCE 2/
Nashua R. at E. Pepperell, Mass.	7	316	62	66	(a)
Merrimack R. at Lowell, Mass.	7	4,425	790	885	(a)
White R. at W. Hartford, Vt.	8	690	75	78	(b)
Conn. R. at White R. Jct., Vt.	8	4,092	810	730	(b)
Chicopee R. nr. Indian Orchard, Mass.	8	688	148	102	(a)
Conn. R. at Thompsonville, Conn.	8	9,661	1,920	2,050	(a)
Grass R. at Pyrites, N. Y.	11	335	64	62	(k)
Walkill R. at Pellets Is. Mtn., N.Y.	12	385	14	12	(c)
Del. R. at Trenton, N. J.	15	6,780	1,285	1,270	(d)
Schuylkill R. at Pottstown, Pa.	15	1,147	230	190	(j) 1/
Brandywine Cr. at Chadds Ford, Pa.	15	287	64	46	(c)
W. Br. Susquehanna R. at Renovo, Pa.	17	2,975	140	185	(e)
W. Br. Sus. R. at Williamsport, Pa.	17	5,682	420	330	(e)
Susquehanna R. at Wilkes-Barre, Pa.	17	9,960	615	580	(c)
Juniata R. at Newport, Pa.	17	3,354	270	200	(e)
Susquehanna R. at Harrisburg, Pa.	17	24,100	1,675	1,700	(j)
S. Br. Potomac R. nr. Petersburg, Va.	19	642	37	32	(f)
S. Fork Shen. R. at Front Royal, Va.	19	1,638	165	225	(g)
Shenandoah R. at Millville, W.Va.	19	3,040	230	300	(g)
Potomac R. at Pt. of Rocks, Md.	19	9,651	595	640	(c)
Rappahannock R. nr. Fredrksbg, Va.	20	1,599	17	7.5	(c)
N. Anna R. nr Doswell, Va.	20	439	5	3	(h)
S. Anna R. nr Ashland, Va.	20	393	6	5	(h)
James R. at Scottsville, Va.	21	4,571	390	390	(i)
James R. at Cartersville, Va.	21	6,242	450	409	(i)
Appomattox R. nr. Petersburg, Va.	21	1,355	32	25	(i)

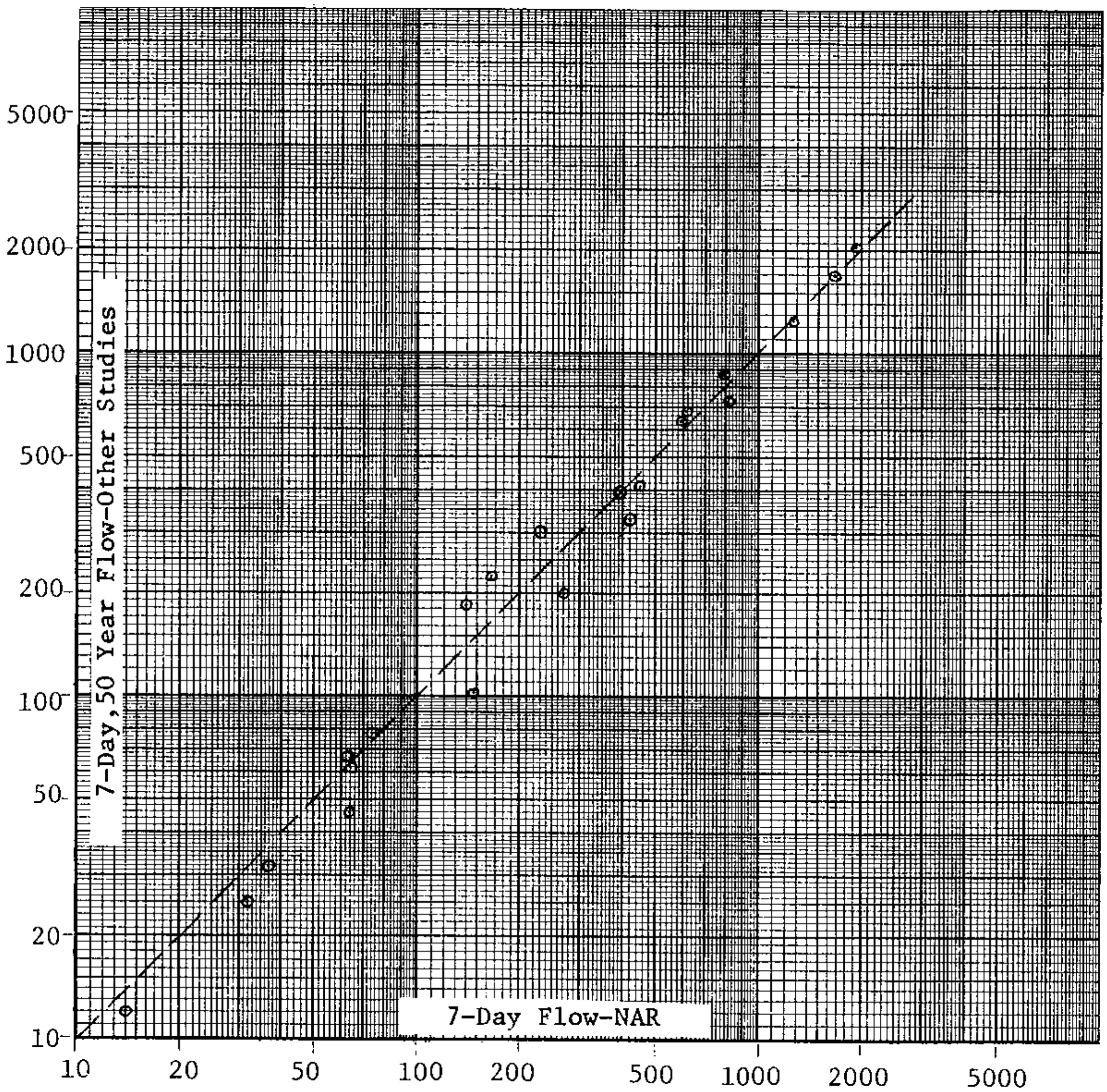
1/ Flows listed are given in source references as seven-day minimum flows having recurrence intervals of about 50 years. Flows for Schuylkill River at Pottstown, Pa., are extrapolated from seven-day, 40-year value on frequency curve.

2/ Sources:
- (a) G. R. Higgins, Yield of Streams in Massachusetts, Water Resources Research Center, University of Massachusetts, March 1967.
- (b) Connecticut River Basin coordinating Committee, Connecticut River Basin Study, "Appendix C - Hydrology," June 1970.
- (c) U. S. Geological Survey, "Low-Flow Frequency Curves for Selected Long Term Gaging Stations in Eastern United States," Water Supply Paper 1669-G, 1963.
- (d) U. S. Congress, House of Representatives, "Delaware River Basin — New York, New Jersey, Pennsylvania and Delaware" House Document No. 522, Vol. VI.

TABLE C-19 (Cont.)
COMPARISON OF SEVEN-DAY MINIMUM FLOWS

(e) Susquehanna River Basin Study Coordinating Committee, Susquehanna River Basin Study, "Appendix D - Hydrology," June 1970.
(f) U. S. Army Corps of Engineers, Potomac River Basin Study, "Appendix D - Hydrology," February 1963.
(g) Commonwealth of Virginia, Potomac-Shenandoah River Basin Comprehensive Water Resources Plan, Vol. III, Planning Bulletin 208, 1969.
(h) Commonwealth of Virginia, York River Basin Comprehensive Water Resources Plan, Vol. III, Planning Bulletin 277, 1970.
(i) Commonwealth of Virginia, James River Basin Comprehensive Water Resources Plan, Vol. III, Planning Bulletin 213, 1969.
(j) Commonwealth of Pennsylvania and U. S. Geological Survey, "Pennsylvania Streamflow Characteristics, Low-Flow Frequency and Flow Duration," Water Resources Bulletin No. 1, April 1966.
(k) U. S. Army Corps of Engineers, data provided by Buffalo District, North Central Division.

FIGURE C-14
COMPARISON OF SEVEN-DAY MINIMUM FLOWS
(All values in c.f.s.)



Although the various other studies were not completely consistent in the methodology used in frequency analysis, it is believed that the results are satisfactory for these comparative purposes. Some adjustments were made, particularly in the case of large areas most pertinent to the Area and Sub-area results in the Sub-regional Summaries, in order to achieve better agreement with established low flow-frequency data.

Table C-19 compares the results of the NAR low flow analysis at representative stations for which frequency information was available. This data is also shown graphically in Figure C-14. While variation is noted at individual stations, the data are generally comparable. On the basis of the comparison, NAR minimum flows are considered to be approximately equivalent to seven-day flows having 50-year recurrence intervals.

It should be noted that Sub-area minimum flow data developed in the Sub-regional Summaries for use in existing resource analyses in Appendix E and the NAR Supply Model are for relatively large areas (from several hundred to thousands of square miles). In most cases, it was possible to base the Sub-area minimum flows on stations having large drainage areas. These stations generally exhibit less variation in the comparison analysis as shown in Figure C-14.

ANALYSIS OF FLOOD CONTROL IMPOUNDMENT EFFECTS

The objective of these hydrologic analyses was to develop techniques for evaluating the regulatory effects of potential major flood control impoundments for use in framework planning. Only the effects of impoundments on major streams is discussed here. The effects of upstream storage on flood reduction is contained in Appendix 7. Techniques were developed for deriving flood peak discharge-frequency and damage-frequency relations for regulated conditions at downstream locations. Based on results obtained from applying these techniques at selected locations, generalized relationships of reduction in average annual damages versus percent area controlled for specified amounts of flood control storage were developed. These generalized relationships can be used for estimating reductions in average annual damages for potential flood control impoundments.

The hydrologic analyses were performed in four major phases as follows: (1.) Development of generalized unit hydrograph and loss rate criteria; (2.) Development of hypothetical storm; (3.) Evaluation of regulatory effects of flood control storage for selected impoundments sites and downstream control points; and (4.) Development of generalized flood control storage-damage reduction relationships.

Several hydrologic techniques were used for evaluating the regulatory effects of potential flood control impoundments. The generalized relationships developed for estimating reductions in average annual damages were based on a multiple regression analysis of results obtained from flood control operation studies for potential impoundments sited in various river basins within the NAR area. The flood control operation was simulated for each selected impoundment by routing hypothetical floods through predetermined amounts of flood control storage. The hypothetical flood hydrographs were developed from a hypothetical storm and generalized unit hydrograph and loss rate criteria. The resulting outflow hydrographs were routed to selected control points to determine regulated flow conditions and associated residual average annual damages. The various hydrologic techniques were programmed and the computations were accomplished on an electronic computer by the Corps of Engineers Hydrologic Engineering Center.

UNIT HYDROGRAPH AND LOSS RATE STUDIES

It was necessary to develop generalized unit hydrograph and loss rate criteria that would be adaptable for regional application to facilitate the computation of flood hydrographs at a large number of locations. Accordingly, areas for which adequate storm rainfall and runoff data were readily available were selected for study. Historical runoff data for 81 streamgaging stations, which reflect little or no control of upstream runoff, were analyzed for a total of 212 major flood events. Unit hydrograph and loss rate coefficients were derived for each flood event. The results of a multiple regression analysis of the unit hydrograph and loss rate coefficients were used to develop generalized criteria that would be adaptable to any area within the Region. Table C-20 lists pertinent data on the 81 locations selected for study, including information on some of the results obtained. The locations of the 81 areas are shown on Figure C-15.

Unit Hydrographs

The Clark[1/] Method was used for deriving unit hydrographs. The unit hydrograph, as used in computer application, is expressed as a function of drainage area (DA), time of concentration (TC), basin storage coefficient (R), and the time-area relationship for the basin. The two unit hydrograph characteristics, TC and R, are highly interdependent, thus results of multiple regression analyses are not generally as dependable for individual values of TC and R as for their sum, TC+R. For this reason, the ratio of R/TC+R was used to express the relationship between TC and R, and only the sum, TC+R, was used in relating these unit hydrograph characteristics to basin characteristics. The basin characteristics found to be the most significant in the correlation studies were drainage area and stream slope. All correlations investigated indicated large residual errors due to the impossibility of expressing many relevant factors numerically. The most effective relationship developed was the following one:

$$(TC + R) = 10(a)\left(\frac{DA}{S}\right)^{0.25} \quad \text{(Equation 1)}$$

in which:

1/ Clark, C.O., "Storage and the Unit Hydrograph", ASCE Transactions Vol. 110, 1945.

TABLE C-20
BASIC FLOOD DATA ON GAGED DRAINAGE BASINS

Map No.	Stream and Station	Basin Characteristics DA sqmi.	NAP in	Sst ft/mi	L mi	a	Unit Hydrograph Data TC+R hr	R/TC+R	R hr	TC hr	Loss Coef. Ko
	JAMES RIVER BASIN (HYDROLOGIC AREA 21.)										
1.	Craig Creek Parr, Va	331	41.5	12.0	57	1.48	34.0	0.29	9.7	24.3	0.23
2.	Appomattox River Farmville, Va	306	44.0	8.5	40	2.37	58.0	0.21	12.4	45.6	0.44
3.	Willis River Flanagan Mills, Va	247	44.0	7.4	47	1.10	26.5	0.72	19.1	7.4	0.43
4.	Jackson River Falling Spring, Va	409	40.5	38.0	56	1.53	27.7	0.36	9.9	17.8	0.16
5.	Maury River nr Buena Vista, Va	649	42.0	17.5	66	1.43	35.4	0.45	15.8	19.6	0.42
6.	Rivanna River Palmyra, Va	675	45.5	9.0	50	1.50	44.2	0.48	21.3	22.9	0.39
	RAPPAHANNOCK RIVER BASIN (HYDROLOGIC AREA 20.)										
7.	RAPPAHANNOCK RIVER nr Fredericksburg, Va	1599	43.5	6.8	78	1.24	48.7	0.25	12.3	36.4	0.20
	POTOMAC RIVER BASIN (HYDROLOGIC AREA 19.)										
8.	Middle River nr Grottoes, Va	360	38.0	9.8	66	1.18	29.0	0.43	12.5	16.5	0.29
9.	S Branch Potomac River nr Petersburg, W Va	642	35.0	29.5	62	1.18	25.6	0.49	12.6	13.0	0.22
10.	N Branch Potomac River Kitzmiller, Md	225	43.5	36.9	29	1.13	17.8	0.64	11.4	6.4	0.15
11.	Georges Creek Franklin, Md	72	42.0	63.2	18	1.23	12.7	0.61	7.8	4.9	0.58
12.	N Fk Shenandoah River Cootes Store, Va	215	33.0	39.9	24	1.19	18.1	0.56	10.2	7.9	0.29
13.	Cacapon River nr Great Cacapon, W Va	677	34.5	7.5	99	1.70	47.4	0.18	8.7	38.7	0.05
14.	Opequon Creek nr Martinsburg, W Va	272	37.0	6.3	55	1.31	33.5	0.31	10.5	23.0	0.30
15.	Conococheague Creek Fairview, Md	494	40.5	18.4	62	2.00	45.5	0.50	22.8	22.7	0.35

TABLE C-20 CONT.
BASIC FLOOD DATA ON GAGED DRAINAGE BASINS

Map No.	Stream and Station	Basin Characteristics: DA sqmi.	NAP in	Sst ft/mi	L mi	a	Unit Hydrograph Data: TC+R hr	R/TC+R	R hr	TC hr	Loss Coef Ko
16.	Monocacy River nr Frederick, Md	817	43.5	5.5	65	1.17	41.0	0.30	12.4	28.6	0.31
17.	Senaca Creek Dawsonville, Md	101	41.0	15.0	19	0.95	15.3	0.42	6.5	8.8	0.23
	SUSQUEHANNA RIVER BASIN (HYDROLOGIC AREA 17.)										
18.	Conodoguinet Creek Hogestown, Pa	470	44.0	8.5	73	1.99	54.2	0.21	11.5	42.7	0.33
19.	Frankstown Br Juniata R Williamsburg, Pa	291	43.0	11.0	35	1.09	24.7	0.14	3.4	21.3	0.01
20.	Sinnemahoning Creek Sinnemahoning, Pa	685	44.0	11.5	40	0.93	25.8	0.39	10.1	15.7	0.28
21.	Penn Creek Penns Creek, Pa	301	43.5	20.0	45	1.64	32.3	0.70	22.6	9.7	0.34
22.	Pine Creek Cedar Run, Pa	604	37.5	19.5	29	1.19	28.1	0.64	18.1	10.0	0.22
23.	Tuscarora Creek nr South Addison, NY	114	36.5	46.3	16	1.07	13.4	0.60	8.0	5.4	0.12
24.	Lycoming Creek nr Trout Run, Pa	173	41.0	50.0	21	0.69	9.4	0.56	5.3	4.1	0.22
25.	East Mahantango Creek nr Dalmatia, Pa	162	45.5	10.2	31	1.72	34.4	0.64	21.9	12.5	0.38
26.	Fishing Creek nr Bloomsburg, Pa	274	46.0	33.3	32	1.62	27.5	0.60	16.4	11.1	0.37
27.	Tunkhannock Creek Dixon. Pa	383	43.5	16.4	34	1.18	26.0	0.25	6.5	19.5	0.02
28.	Owego Creek nr Owego, NY	186	38.0	16.7	28	1.03	18.8	0.57	10.8	8.0	0.18
29.	Tioughnioga River Cortland, NY	296	40.5	9.8	28		31.2	0.71	22.0	9.2	0.12
30.	Unadilla River nr New Berlin, NY	196	41.5	5.4	30	1.54	37.8	0.40	15.2	22.6	0.07
31.	Charlotte Creek West Davenport, NY	167	42.5	19.5	23	1.53	26.0	0.46	11.9	14.1	0.15
	DELAWARE RIVER BASIN (HYDROLOGIC AREA 15.)										
32.	Little Delaware River nr Delhi, NY	50	42.5	50.7	15	1.20	12.0	0.74	8.9	3.1	0.44
33.	Beaver Kill Craigie Clair, NY	82	50.5	57.0	23	0.99	10.8	0.43	4.6	6.2	0.11
34.	Callicoon Creek Callicoon, NY	111	43.5	34.8	19	1.11	14.9	0.74	11.0	3.9	0.23

TABLE C-20 CONT.
BASIC FLOOD DATA ON GAGED DRAINAGE BASINS

Map No.	Stream and Station	Basin Characteristics DA sqmi.	NAP in	Sst ft/mi	L mi	a	Unit Hydrograph Data TC+R hr	R/TC+R	R hr	TC hr	Loss Coef. Ko
35.	Lackawaxen River Hawley, Pa	290	43.0	22.7	33	1.07	20.2	0.52	10.5	9.7	0.14
36.	Bush Kill Shoemakers, Pa	117	45.5	37.5	23	1.89	25.1	0.48	12.1	13.0	0.27
37.	Lehigh River Tannery, Pa	322	45.5	24.3	32	1.66	31.6	0.41	12.9	18.7	0.30
38.	Little Schuylkill River Tamaqua, Pa	43	49.5	69.7	12	1.75	15.5	0.60	9.3	6.2	0.56
39.	Schuylkill River Berne, Pa	355	47.5	17.4	36	1.68	35.7	0.68	24.3	11.4	0.38
40.	Monocacy Creek Bethlehem, Pa	44	42.5	19.5	14	1.53	18.8	0.49	9.3	9.5	0.55
41.	Pequest River Pequest NJ	108	43.0	5.8	25	0.78	16.1	0.71	11.4	4.7	0.44
42.	White Clay Creek Above Newark, Del	67	43.5	20.1	15	0.70	9.4	0.49	4.6	4.8	0.38
43.	Leipsic River nr Cheswold, Del	9	43.0	10.0	4	2.25	22.0	0.52	11.5	10.5	0.37
44.	Salem River Woodstown, NJ	15	44.0	14.3	6	1.51	15.2	0.42	6.4	8.8	0.31
45.	Neshaminy Creek nr Langhorne, Pa	210	42.5	15.3	34	1.06	20.4	0.26	5.3	15.1	0.13
	PASSAIC RIVER BASIN (HYDROLOGIC AREA 14.)										
46.	Passaic River nr Chatham, NJ	100	48.0	8.4	27	1.85	34.3	0.84	28.7	5.6	0.58
47.	Rockaway River Boonton, NJ	116	48.5	17.4	31	2.56	41.2	0.48	19.9	21.3	0.43
48.	Elizabeth River Elizabeth, NJ	18	47.0	9.2	18	0.74	8.8	0.24	2.1	6.7	0.41
49.	Saddle River Lodi, NJ	55	46.5	8.4	19	2.94	47.0	0.34	15.9	31.1	0.26
50.	Ramapo River Pompton Lakes, NJ	160	48.0	10.0	34	2.58	51.7	0.22	11.3	40.4	0.52
	COASTAL AREA (HYDROLOGIC AREA 13.)										
51.	Mamaroneck River Mamaroneck, NY	23	45.0	42.1	12	1.82	15.7	0.39	6.1	9.6	0.79

TABLE C-20 CONT.
BASIC FLOOD DATA ON GAGED DRAINAGE BASINS

Map No.	Stream and Station	Basin Characteristics DA sqmi.	NAP in	Sst ft/mi	L mi	a	Unit Hydrograph Data TC+R hr	R/TC+R	R hr	TC hr	Loss Coef. Ko
	HUDSON RIVER BASIN(HYDROLOGIC AREA 12.)										
52.	Rondout Creek Rosendale, NY	292	50.0	23.7	41	0.94	17.7	0.60	10.6	7.1	0.46
53.	Little Wappinger Creek Salt Point, NY	32	41.0	16.4	16	2.70	32.0	0.30	9.6	22.4	0.05
54.	Wappinger Creek nr Clinton Corners, NY	91	42.0		18						0.32
55.	Wappinger Creek nr Wappingers Falls, NY	182	41.5	8.5	34	1.44	31.0	0.30	9.4	21.6	0.26
56.	Hoosic River nr Williamstown, Mass	132	49.0	30.1	24	1.24	17.9	0.73	13.1	4.8	0.28
57.	Walloomsac River nr North Bennington, Vt	111	46.0	78.7	18	1.94	21.1	0.43	9.1	12.0	0.40
	LAKE CHAMPLAIN BASIN (HYDROLOGIC AREA 11.)										
58.	Mad River nr Moretown, Vt	139	43.5	32.1	21	0.94	13.6	0.40	5.4	8.2	0.41
59.	Dog River Northfield Falls, Vt	76	41.0	63.9	15	1.31	13.7	0.34	4.6	9.1	0.56
	HOUSATONIC RIVER BASIN (HYDROLOGIC AREA 10.)										
60.	Naugatuck River nr Thomaston, Conn	72	48.0	27.4	19	1.31	16.7	0.57	9.6	7.1	0.28
61.	Leadmine Brook nr Thomaston, Conn	24	48.0	54.0	11	0.71	5.8	0.19	1.1	4.7	0.45
	CONNECTICUT RIVER BASIN (HYDROLOGIC AREA 8.)										
62.	Valley Brook nr West Hartland, Conn	7	47.0	79.7	6	1.46	8.0	0.30	2.4	5.6	0.81
63.	West Br Farmington R nr New Boston, Mass	75	49.5	48.8	19	0.90	10.0	0.64	6.4	3.6	0.05
64.	Middle Br Westfield R Goss Heights, Mass	53	48.0	74.0	19	0.68	6.2	0.60	3.7	2.5	0.20
65.	West River Newfane, Vt	308	45.5	27.4	40	0.91	16.7	0.52	8.6	8.1	0.22
66.	Otter Brook nr Keene, NH	42	41.0	62.0	12	1.89	17.2	0.65	11.1	6.1	0.24
67.	Williams River Brockways Mills, Vt	103	42.5	78.8	22	1.27	13.6	0.45	6.1	7.5	0.33

TABLE C-20 CONT.
BASIC FLOOD DATA ON GAGED DRAINAGE BASINS

Map No.	Stream and Station	Basin Characteristics DA sqmi.	NAP in	Sst ft/mi	L mi	a	Unit Hydrograph Data TC+R hr	R/TC+R	R hr	TC hr	Loss Coef. Ko.
68.	Black River North Springfield, Vt	123	44.5	20.0	30	1.23	19.4	0.43	8.4	11.0	0.25
69.	Ottauquechee River North Hartland, Vt	221	43.5	40.4	38	1.23	18.8	0.48	9.0	9.8	0.19
	MERRIMACK RIVER BASIN (HYDROLOGIC AREA 7.)										
70.	Baker River Wentworth, NH	59	48.0	187.0	12	1.87	14.0	0.47	6.6	7.4	0.46
71.	N Branch Contoocook R nr Antrim, NH	55	46.5	36.5	24						0.51
72.	Contoocook River nr Bennington, NH	186	44.0	27.0	20	3.89	63.0	0.53	33.1	29.9	0.21
73.	Piscataquog River nr Goffstown, NH	104	44.0	26.2	22	2.27	32.1	0.49	15.6	16.5	0.34
	THAMES RIVER BASIN (HYDROLOGIC AREA 10.)										
74.	Quinebaug River Westville, Mass	94	45.5	18.6	20	1.86	27.8	0.59	16.5	11.3	0.43
75.	Quinebaug River above Westville, Mass	63	44.5	26.0	15	1.58	19.7	0.58	11.5	8.2	0.13
	KENNEBEC RIVER BASIN (HYDROLOGIC AREA 3.)										
76.	Sandy River nr Mercer, Maine	514	43.5	13.1	62	1.98	48.9	0.46	22.7	26.2	0.11
77.	Austin Stream Bingham, Maine	91	42.5	58.7	18	3.10	34.6	0.70	24.2	10.4	0.02
	PENOBSCOT RIVER BASIN (HYDROLOGIC AREA 2.)										
78.	Pleasant River nr Milo, Maine	322	44.5	32.7	39	2.26	40.0	0.41	16.4	23.6	0.00
	ST. JOHN RIVER BASIN (HYDROLOGIC AREA 1.)										
79.	Aroostook River Washburn, Maine	1652	39.5	4.1	90	2.26	101.1	0.43	43.3	57.8	0.02
80.	Allagash River Allagash, Maine	1250	40.0	4.3	104	2.36	97.3	0.32	31.1	66.2	0.14
81.	St. John River Ninemile Bridge, Me	1290	40.5	6.8	62	2.17	81.3	0.47	38.1	43.2	0.20

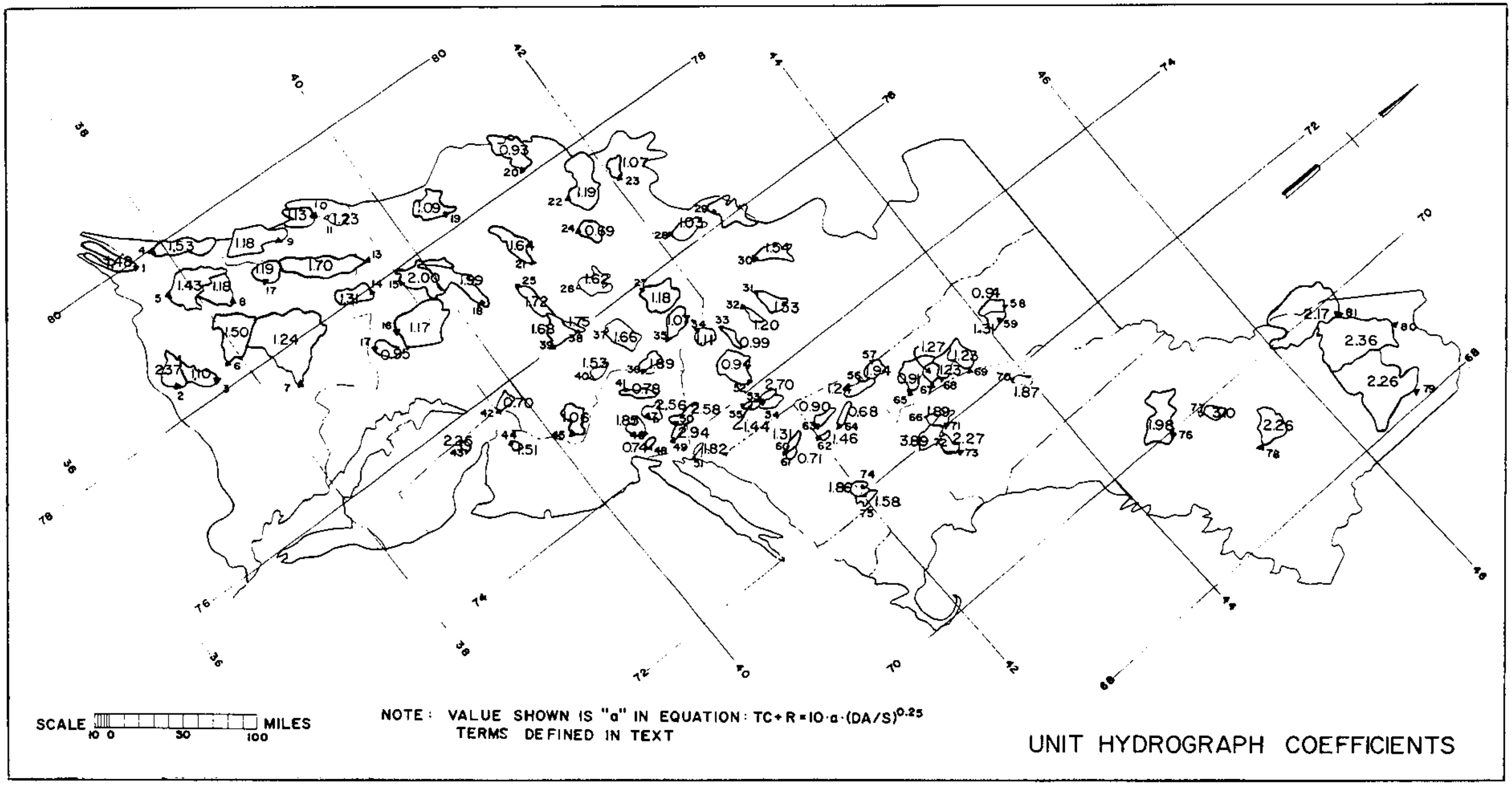


FIGURE C-15

81 AREAS FOR FLOOD CONTROL STUDY AND UNIT HYDROGRAPH COEFFICIENTS

TC = Time of concentration in hours,
R = Basin storage coefficient in hours,
DA = Drainage area in square miles,
S = Slope of the main watercourse in feet/mile,
a = Basin characteristics coefficient

Values of the basin characteristic coefficient "a" in Equation 1 for each of the 81 areas studied are shown on Figure C-15 and are listed in Table C-20. Values of the ratio R/(TC+R) for the same areas are also listed in Table C-20. Using Equation 1, unit hydrograph coefficients for the characteristics TC and R can be computed and used for deriving synthetic unit hydrographs for other areas in the Region by determining the size (DA) and slope (S) of an area and by interpolation of "a" and R/(TC+R) values from Figure C-15 and Table C-20, respectively.

Loss Rates

For specified ground conditions such as vegetal cover, soil moisture and surface detention, loss rates tend to increase as rainfall rates increase when expressed as basin-mean amounts. Also loss rates generally decrease as ground wetness conditions increase during storm events. Basin-mean loss rates are usually curvilinear functions of basin-mean rainfall. The functions as used in computer application to express the above relations between loss rates and rainfall are as follows:

$$L = KP^E \quad \text{(Equation 2), and}$$

$$K_i = \frac{K_o}{F^{(.1\Sigma L_i)}} \quad \text{(Equation 3)}$$

In which:

L = Loss rate in inches per hour
P = Rainfall rate in inches per hour
K = Constant dependent on wetness of the ground
E = Exponent between 0 and 1
K_i = Current value of loss coefficient K
K_o = Starting value of loss coefficient K
F = Ratio of K to its value after 10 inches or more accumulated loss has taken place
ΣL_i = Current accumulated loss in inches

From an analysis of the loss rate coefficients derived for each flood event, a value of 0.5 for the exponent E in Equation 2 and a value of 3.0 for the ratio F in Equation 3 were selected as regional average values. Corresponding values derived for the initial loss coefficient (K_o) in Equation 3 are listed in Table C-20. A value of 0.2 for K_o was also selected as a Regional average value. The above loss rate coefficients for E,F, and K_o were adopted for use as generalized loss rate criteria applicable to the entire North Atlantic Region.

DEVELOPMENT OF HYPOTHETICAL STORMS

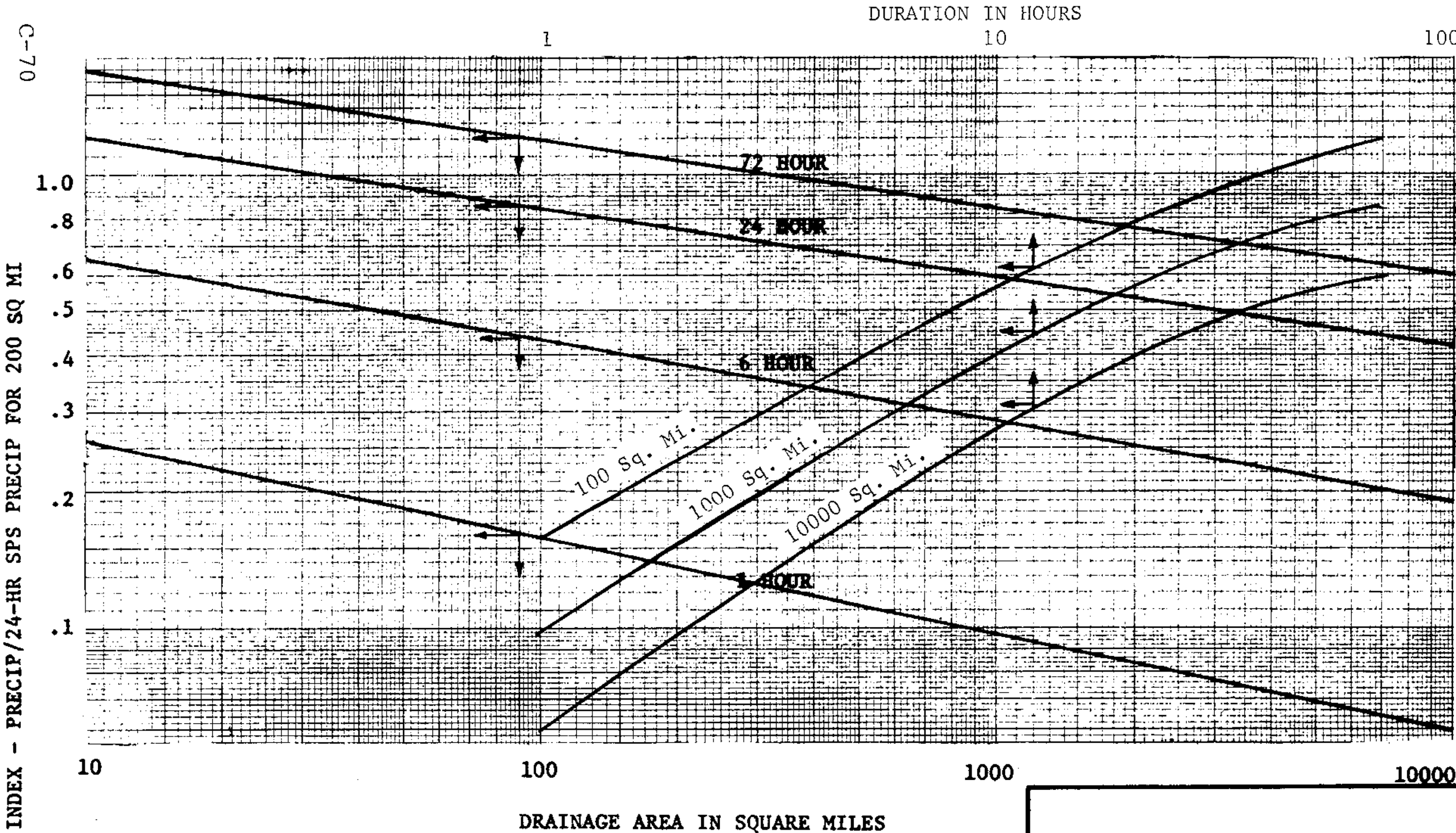
Historical storm data for the Northeastern United States were analyzed to determine criteria for development of a well-balanced hypothetical storm of intermediate magnitude. Maximum depth-area-duration data for areas of 100, 1,000 and 10,000 square miles and durations of 1, 6, 24 and 72 hours were determined. For each area, the storm magnitudes were expressed as ratios to the 24-hour 200-square mile standard project storm precipitation, in order to compensate for geographical and topographical effects inherent in the basic data. A logarithmic depth-duration relationship was selected for each area which would envelope historical storms that have been exceeded by about 10 to 12 events of record in the Region. The depth-duration relationships for areas of 100, 1,000 and 10,000 square miles and the adopted depth-area relationships for durations of 1, 6, 24 and 72 hours are shown on Figure C-16.

The precipitation time distribution patterns for the historical storms were also studied to develop a pattern for the hypothetical storm. A pattern was adopted which placed the maximum precipitation near the middle of the 72-hour duration storm and conformed generally to the standard project storm distribution explained in Corps of Engineers publication, EM 1110-2-1411. The resulting precipitation time distribution pattern is shown in Table C-21 for 100 and 10,000 square-mile drainage areas. Distribution patterns for other area sizes can be obtained by logarithmic interpolation.

CONTROL POINTS

In order to assess reductions in discharge, stage and damage resulting from regulatory effects of flood control storage, it was necessary to select control points for which data on discharge-stage, discharge-frequency and stage-damage relations were readily available. Most of the drainage basins at each control point were divided into logical sub-basins to facilitate the computation of flood hydrographs. The locations of the twenty-two control points and associated sub-basins selected for study are shown on Figure C-17. The control points are located in 11 of the 21 NAR Areas.

The basin characteristics and unit hydrograph and loss rate coefficients adopted for each sub-basin are listed in Table C-22, and the basin characteristic coefficient "a" values are also shown on Figure C-18. The adopted "a" values, ranging from 1.5 to 3.2, are generally 20% to 50% larger than those derived from the unit hydrograph studies described previously (See Figure C-15). Based on an analysis of historical major floods at the control points and locations upstream



DEPTH-AREA-DURATION CURVES

FIGURE C-16

Hydrologic Engineering Center
U. S. Army Corps of Engineers

TABLE C-21
HYPOTHETICAL STORM
Hourly Percentages of 72-hour Storm Rainfall

TIME (Hours)	100 Sq. Mi. (Percent)	10,000 Sq. Mi. (Percent)	TIME (Hours)	100 Sq. Mi. (Percent)	10,000 Sq. Mi. (Percent)
1	.339	.413	37	2.494	3.182
2	.339	.413	38	4.218	3.213
3	.339	.413	39	6.711	6.395
4	.339	.413	40	13.276	9.700
5	.339	.413	41	5.794	4.896
6	.339	.413	42	4.181	3.213
7	.714	.836	43	1.805	2.155
8	.714	.836	44	1.805	2.155
9	.714	.836	45	1.805	2.155
10	.714	.836	46	1.805	2.155
11	.714	.836	47	1.805	2.155
12	.714	.836	48	1.805	2.155
13	1.658	1.582	49	.177	.222
14	1.658	1.582	50	.177	.222
15	1.658	1.582	51	.177	.222
16	1.658	1.582	52	.177	.222
17	1.658	1.582	53	.177	.222
18	1.658	1.582	54	.177	.222
19	.490	.669	55	.372	.450
20	.490	.669	56	.372	.450
21	.490	.669	57	.372	.450
22	.490	.669	58	.372	.450
23	.490	.669	59	.372	.450
24	.490	.669	60	.372	.450
25	1.251	1.331	61	.863	.851
26	1.251	1.331	62	.863	.851
27	1.251	1.331	63	.863	.851
28	1.251	1.331	64	.863	.851
29	1.251	1.331	65	.863	.851
30	1.251	1.331	66	.863	.851
31	2.631	2.697	67	.255	.361
32	2.631	2.697	68	.255	.361
33	2.631	2.697	69	.254	.361
34	2.631	2.697	70	.254	.361
35	2.631	2.697	71	.254	.361
36	2.631	2.697	72	.254	.360

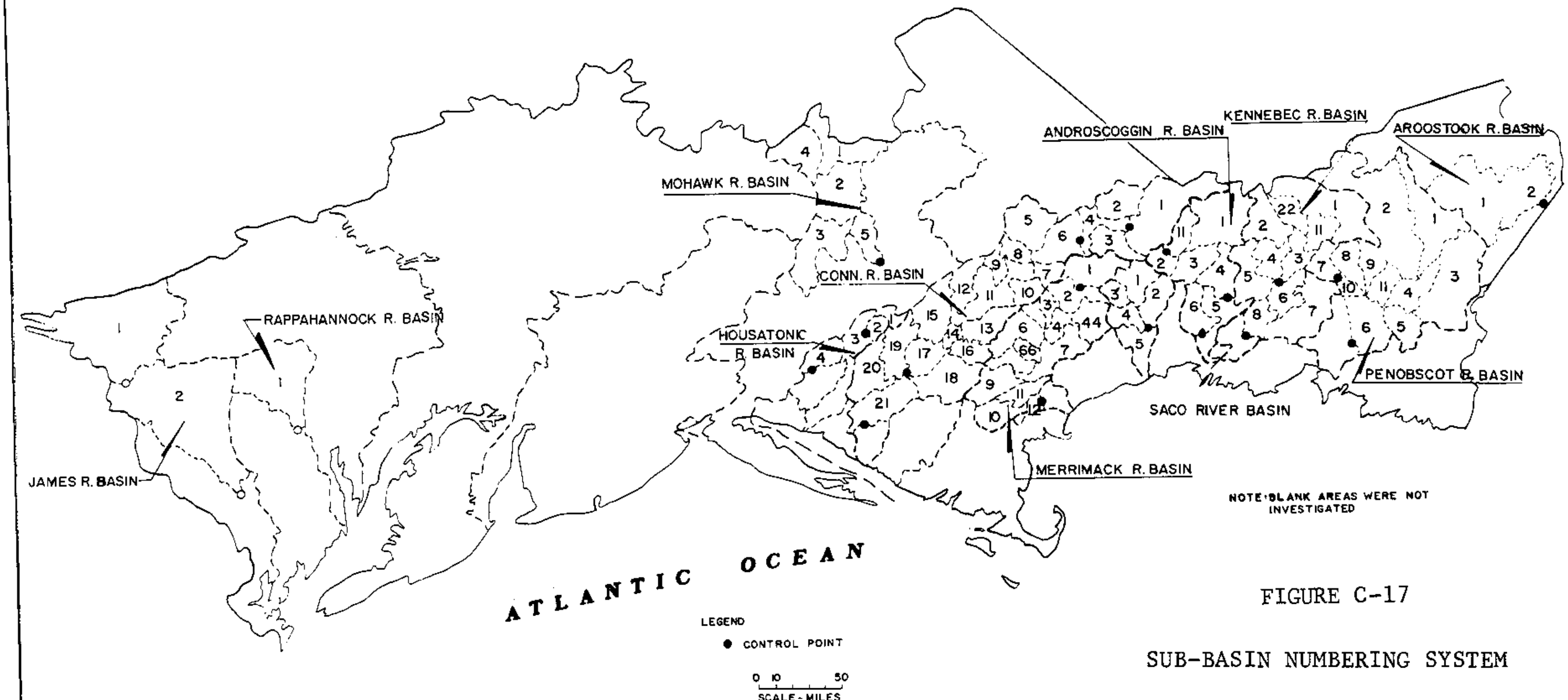


FIGURE C-17

SUB-BASIN NUMBERING SYSTEM

TABLE C-22
BASIC FLOOD DATA BY DRAINAGE SUB-BASINS

Sub-basin Number	Basin Characteristics DA SqMi	NAP In	Sst Ft/Mi	L Mi	a	Unit Hydrograph Data TC+R Hr	R / TC+R	R Hr	TC Hr	QRCSN CFS	RTIOR
CONNECTICUT RIVER BASIN											
1	1514	46	4.0	93.5	3.0	132.2	0.5	66.1	66.1	13300	1.17
2	507	45	26.2	41.0	2.5	52.4	0.5	26.2	26.2	5240	1.37
3	395	48	15.5	50.0	2.5	56.2	0.5	28.1	28.1	5240	1.38
4	435	42	5.6	47.7	3.0	88.8	0.5	44.4	44.4	3650	1.23
5	690	41	11.6	47.0	2.5	69.8	0.5	34.9	34.9	4840	1.24
6	551	40	12.2	54.0	3.0	77.8	0.5	38.9	38.9	3790	1.25
7	221	40	45.3	24.0	2.0	29.8	0.5	14.9	14.9	1830	1.46
8	194	44	32.0	33.5	2.0	31.4	0.5	15.7	15.7	2240	1.50
9	204	44	19.3	34.0	2.5	45.0	0.5	22.5	22.5	2320	1.43
10	269	40	35.5	24.0	2.0	33.2	0.5	16.6	16.6	2130	1.41
111	513	42	2.3		3.0	116.0	0.5	58.0	58.0	4190	1.18
211	350	42	2.3	74.0	3.0	105.4	0.5	52.7	52.7	3080	1.19
12	423	48	18.7	51.5	2.5	54.6	0.5	27.3	27.3	5320	1.38
13	420	42	17.3	36.3	2.5	55.6	0.5	27.8	27.8	3540	1.32
14	123	44	4.1	17.0	2.5	58.4	0.5	29.2	29.2	1550	1.32
15	664	52	24.8	70.6	2.5	56.2	0.5	28.1	28.1	10300	1.42
16	392	42	22.5	35.2	2.5	51.0	0.5	25.5	25.5	3370	1.35
17	419	44	1.7	52.0	3.0	118.8	0.5	59.4	59.4	4270	1.18

TABLE C-22 CONT.
BASIC FLOOD DATA BY DRAINAGE SUB-BASINS

Sub-basin Number	Basin Characteristics DA SqMi	NAP In	Sst Ft/Mi	L Mi	a	Unit Hydrograph Data TC+R Hr	R/TC+R	R Hr	TC Hr	QRCSN CFS	RTIOR
CONNECTICUT RIVER BASIN (Cont'd)											
18	472	43	14.0	54.0	3.0	72.2	0.5	36.1	36.1	4240	1.30
19	301	47	13.0	48.0	3.0	65.8	0.5	32.9	32.9	3910	1.38
20	443	48	11.2	74.0	3.0	75.0	0.5	37.5	37.5	5720	1.33
21	764	44	0.4	42.2	3.0	116.0	0.5	58.0	58.0	6740	1.11
HOUSATONIC RIVER BASIN											
1	130	48	51.9	14.0	2.0	31.5	0.6	18.9	12.6	2140	1.72
2	150	47	11.4	30.5	1.3	47.6	0.6	28.9	19.0	2160	1.44
3	352	46	3.4	33.5	2.5	78.9	0.6	47.9	31.9	4105	1.25
4	362	45	14.0	36.0	1.0	56.3	0.5	28.2	28.1	3965	1.35
SACO RIVER BASIN											
1	442	52	6.5	25.2	1.5	48.0	0.6	28.8	17.2	2763	1.12
2	401	54	3.8	31.0	3.0	96.0	0.6	57.6	38.4	2756	1.11
3	190	47	11.0	22.0	2.0	40.8	0.5	20.4	20.4	1035	1.15
4	265	45	14.0	22.6	3.0	62.7	0.6	37.6	25.1	1137	1.14
5	399	43	8.7	65.0	3.0	78.0	0.6	46.8	31.2	1431	1.11
KENNEBEC RIVER BASIN											
1	1240	42	11.0	109.4	3.0	97.8	0.45	44.0	53.8	8468	1.21
11	320	42	14.3		3.0	65.2	0.45	29.4	35.9	2850	1.32
2	520	44	16.6	73.2	3.0	71.1	0.45	32.0	39.1	4912	1.32
22	358	44	16.6		3.0	64.8	0.45	29.2	35.6	3626	1.35

TABLE C-22 CONT.
BASIC FLOOD DATA BY DRAINAGE SUB-BASINS

	Basin Characteristics					Unit Hydrograph Data					
Sub-basin Number	DA SqMi	NAP In	Sst Ft/Mi	L Mi	a	TC+R Hr	R / TC+R	R Hr	TC Hr	QRCSN CFS	RTIOR
KENNEBEC RIVER BASIN (Cont'd)											
3	362	42	8.0	39.0	3.0	77.7	0.55	42.7	35.0	3133	1.27
4	400	43	34.0	39.9	3.0	55.6	0.45	25.0	30.6	3664	1.68
5	593	43	8.4	37.2	3.0	86.7	0.55	47.7	39.0	5068	1.25
6	407	39	12.3	73.0	3.0	72.0	0.55	39.6	32.4	2736	1.26
7	950	39	7.9	61.0	3.0	99.3	0.55	54.6	44.7	5339	1.19
8	320	39	0.5	18.5	3.0	151.5	0.55	88.3	68.2	2269	1.12
ANDROSCOGGIN RIVER BASIN											
11	1045	44	11.3	67.5	2.5	77.5	0.50	38.8	38.8	8570	1.24
1	318	44	9.9	30.0	2.5	59.2	0.50	29.6	29.6	3330	1.31
2	229	50	4.5	14.5	2.5	67.7	0.50	33.8	33.8	3790	1.33
3	410	47	23.0	23.0	2.5	51.5	0.50	25.7	25.7	5019	1.40
4	494	44	12.8	53.8	2.5	62.2	0.50	31.1	31.1	4714	1.36
5	345	42	22.5	22.3	2.5	49.5	0.50	24.7	24.7	3020	1.36
6	416	43	7.8	43.0	2.5	67.5	0.50	33.7	33.7	3786	1.26
PENOBSCOT RIVER BASIN											
1	860	39	7.8	125.5	3.0	97.2	0.55	53.5	43.7	4938	1.19
2	2120	41	7.7	154.0	3.0	122.1	0.55	67.2	54.9	11901	1.16
3	1490	39	5.5	84.0	3.2	129.6	0.55	71.3	58.3	7578	1.15
4	426	40	2.8	53.5	3.2	112.6	0.55	61.9	50.7	3060	1.18

TABLE C-22 CONT.
BASIC FLOOD DATA BY DRAINAGE SUB-BASINS

Sub-basin Number	Basin Characteristics DA SqMi	NAP In	Sst Ft/Mi	L Mi	a	Unit Hydrograph Data TC+R Hr	R / TC+R	R Hr	TC Hr	QRCSN CFS	RTIOR
PENOBSCOT RIVER BASIN (Cont'd)											
5	385	40	3.7	44.8	3.2	102.1	0.55	56.2	45.9	2818	1.20
6	715	40	3.6	34.3	3.2	120.3	0.55	66.2	54.1	4650	1.17
7	297	43	18.4	27.5	2.5	50.0	0.45	22.5	27.5	2900	1.37
8	352	42	13.2	53.3	2.5	56.8	0.45	25.6	31.2	3061	1.31
9	334	46	17.4	45.8	2.5	52.5	0.45	23.6	28.9	3963	1.35
10	178	40	3.1	27.8	2.5	68.2	0.45	30.7	37.5	1518	1.24
11	293	40	26.6	13.5	2.5	45.5	0.45	20.5	25.0	2268	1.37
AROOSTOOK RIVER BASIN											
1	1652	40	4.1		3.0	134	0.55	73.7	60.3	12100	1.33
2	578	40	4.3		3.2	109	0.55	59.9	49.1	5200	1.48
JAMES RIVER BASIN											
1	3250	41	8.2	182	1.5	89.0	0.50	44.5	44.5	11247	1.37
2	3507	42	3.6	150	1.5	83.8	0.45	37.7	46.1	12927	1.30
MOHAWK RIVER BASIN											
1	556	44	19.4	79	2.5	57.9	0.50	29.0	28.9	3450	1.88
2	800	40			1.8	60.3	0.50	30.2	30.1	3520	1.14
3	900	39			1.5	44.5	0.40	17.8	26.7	3820	1.18
4	700	38	11.6	66	2.5	80.7	0.50	40.4	40.3	2565	1.13
5	340	36			1.8	48.8	0.50	24.4	24.4	1210	1.18

TABLE C-22 CONT.
BASIC FLOOD DATA BY DRAINAGE SUB-BASINS

Sub-basin Number	Basin Characteristics DA SqMi	NAP In	Sst Ft/Mi	L Mi	a	Unit Hydrograph Data TC+R Hr	R / TC+R	R Hr	TC Hr	QRCSN CFS	RTIOR
RAPPAHANNACK RIVER BASIN											
1	1599	44	6.8	78	1.50	58.7	0.45	26.4	32.3	7730	1.46
MERRIMACK RIVER BASIN											
1	621	47	21.3	38.8	2.3	53.4	0.50	26.7	26.7	7100	1.35
2	379	46	9.5	29.5	2.3	57.8	0.50	28.9	28.9	4366	1.31
3	136	48	43.1	15.5	2.3	30.6	0.50	15.3	15.3	2225	1.68
4	230	42	3.7	33.0	2.3	64.8	0.50	32.4	32.4	2188	1.23
5	150	47	14.2	27.5	2.3	41.4	0.50	20.7	20.7	2248	1.47
6	490	45	7.7	47.0	2.3	65.1	0.50	32.5	32.5	4920	1.27
66	152	44	25.4	21.0	2.3	35.9	0.50	17.9	17.9	1814	1.52
7	652	40	7.3	60.5	3.0	92.1	0.50	46.0	46.0	4355	1.21
8	171	47	33.9	18.0	2.3	34.4	0.50	17.2	17.2	2505	1.58
9	530	44	5.7	49.5	3.0	93.0	0.50	46.5	46.5	4945	1.24
10	406	43	2.2	36.0	3.0	101.1	0.50	50.5	50.5	3725	1.19
11	247	40	11.0	19.0	2.3	49.9	0.50	24.9	24.9	1984	1.30
12	37	40	1.0	5.0	2.3	56.8	0.50	28.4	28.4	435	1.27
44	471	42	3.7	33.0	2.3	77.2	0.50	38.6	38.6	3895	1.20

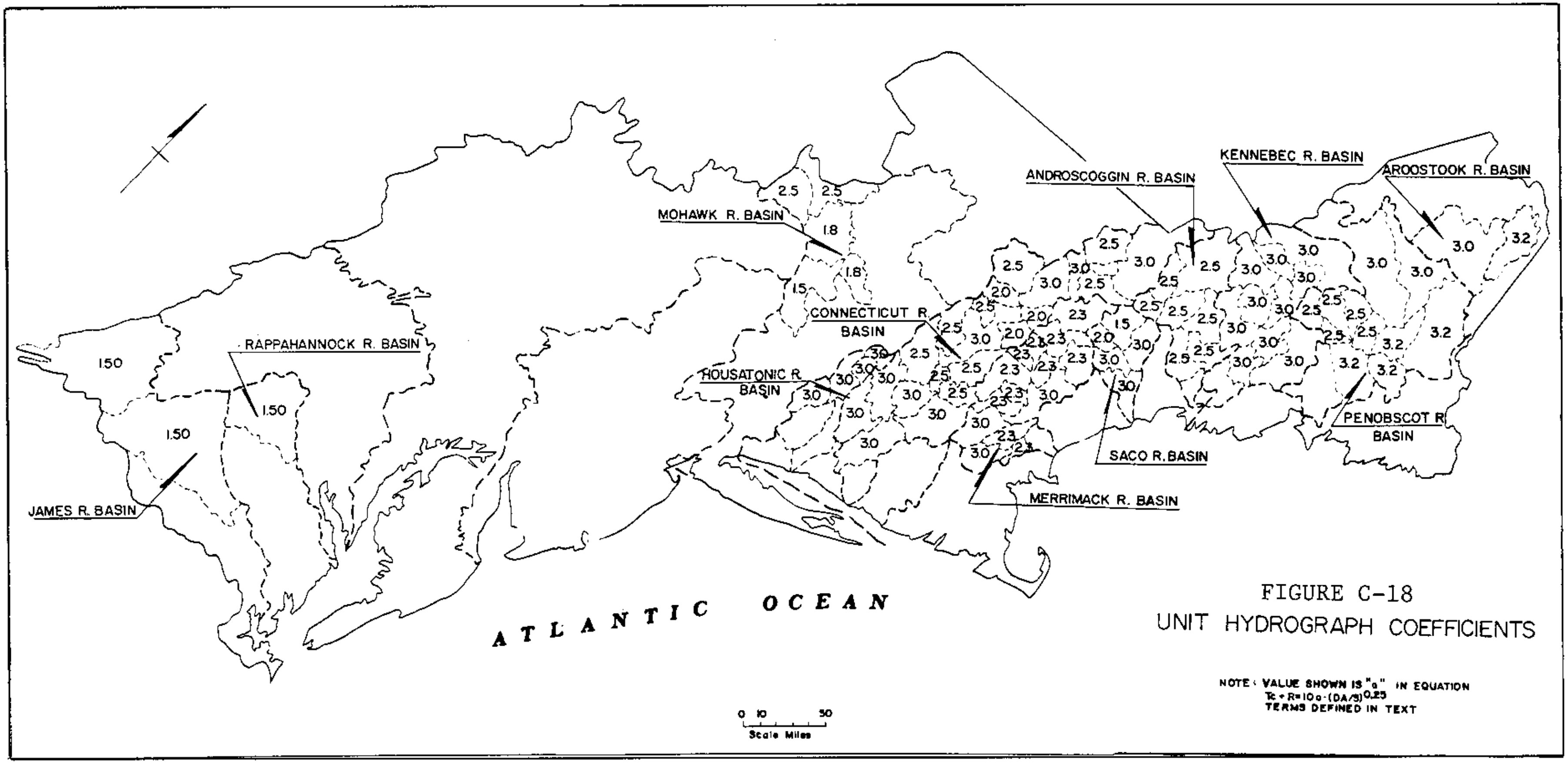


FIGURE C-18
UNIT HYDROGRAPH COEFFICIENTS

thereof, it was found necessary to use these larger "a" values in order to compute hypothetical floods that would be representative of the historical floods as discussed further in the following paragraph. The adopted R/TC+R values ranged from 0.40 to 0.60.

The discharge-frequency curves adopted for the 22 control points are based on available frequency data derived from various Corps of Engineers reports and technical studies. The adopted frequency curves are representative of estimated flow conditions with existing and authorized reservoir projects in operation. To assess the regulatory effects of additional flood control storage above each control point, the portion of each frequency curve that represents the entire range of damaging flood magnitudes was divided into eight frequency intervals. It was assumed that the discharge corresponding to the midpoint of an interval was representative of that frequency interval (increment). The eight increments can be accumulated to determine the combined regulatory effects of the entire range of damaging floods. The eight frequency intervals selected are shown in Table C-23.

TABLE C-23
FLOOD FREQUENCY INTERVALS
(Figures in percent)

FREQUENCY LIMITS	FREQUENCY INTERVAL	FREQUENCY MIDPOINT
0-1	1.0	0.5
1-3	2.0	2.0
3-6	3.0	4.5
6-10	4.0	8.0
10-16	6.0	13.0
16-26	10.0	21.0
26-40	14.0	33.0
40-60 1/	20.0	50.0

1/ The assumption was made that all floods with frequencies larger than 60% are non-damaging floods.

DEVELOPMENT OF HYPOTHETICAL FLOODS

A set of hypothetical floods representative of historical floods was developed for each control point. The computation technique used consisted of deriving a synthetic flood event (base flood) using the hypothetical storm and generalized unit hydrograph and loss rate criteria described above, and computing hypothetical floods of desired frequencies by using appropriate multiples of the base flood. Eight multiples were computed for each control point so as to produce a set of eight hypothetical flood magnitudes corresponding to the given pack discharge for the midpoint of each frequency interval shown in Table C-23.

For the above technique to be applicable, historical flood peak-to-volume ratios must be reasonably uniform for the entire range of flood magnitudes to be evaluated. Then it follows that if the base flood is representative of historical floods, other floods derived as multiples or ratios of the base flood would be equally representative. It was found that if base floods were used whose peaks were of intermediate magnitudes corresponding to frequencies ranging from about once in 10 years to once in 50 years, that peak-to-volume ratios would reasonably represent the entire range of damaging historical floods. For an approximation such as this based on a number of assumptions or constant peak-to-volume ratio appears sufficiently accurate even so various studies indicate that exponential relations with exponents not to far from 1.0 better describe this relation.

FLOOD CONTROL STORAGE SIMULATION

Operation studies for flood control were made of 22 impoundments sited at the selected control points and for 102 impoundments sited upstream, thus providing only partial area control of the drainage area at the respective control points. The flood control operation studies were simulated by routing the set of eight hypothetical flood hydrographs through each impoundment for 0.5, 1, 2, 4 and 7 inches of flood control storage. The resulting outflow flood hydrographs were routed downstream and combined with intervening area flood hydrographs to determine regulated flood hydrographs at each control point.

Release rates were based on preventing flood damages in the river reach immediately below the impoundment sites considered. Average release rates equivalent to .8 of the two year flood peak discharge were made. Whenever the predetermined amounts of flood control storage had been utilized, outflow was made equal to inflow. The regulatory effects of surcharge storage were not evaluated.

Previously established flood routing procedures were used for routing the set of eight outflow hydrographs to each control point, and for routing and combining the sub-basin base flood hydrographs to obtain the base flood hydrographs at each control point. The successive average lag and the Muskingham routing methods were used.

Reductions in average annual damages were computed at each control point for each impoundment by subtracting the average annual damages for project conditions from those for pre-project conditions. The average annual damages for both conditions were determined by integration of the frequency-damage relations using the frequency intervals listed in Table C-23.

Results obtained from the simulated operation studies on the

TABLE C-24
SUMMARY OF REGULATORY EFFECTS OF FLOOD CONTROL STORAGE

No.	River Basin	Damage Center	Subareas Numbers (See Figure)	Drainage Area (Sq. Mi.)	Drainage[1/] Area Controlled (percent)	Average Annual Damages (Dollars)	Percent Average Annual Damage Reduction For Storage @ Dam Site of 0.5 inches	1.0 inches	2.0 inches	4.0[2/] inches	7.0[2/] inches	Maximum Storage Required[2/] (inches)
1	Aroostook	Ft. Fairfield	1,2	2,360	100.0	71600	5.10	27.84	91.33	100.00	100.00	2.79
2	Penobscot	Dover Foxcroft	7	297	100.0	21500	0.36	24.00	72.36	100.00	100.00	3.91
3		Veazie Dam	1-11	7,700	100.0	97500	13.39	56.29	99.89	100.00	100.00	2.19
4			1	860	17.3		18.67	34.42	43.82	44.00	44.00	
5			2	2,120	42.6		3.13	3.13	3.13	3.13	3.13	
6			3	1,490	29.9		23.59	45.73	58.83	58.96	58.96	
7			4-6	1,526	30.7		0.23	4.78	36.82	71.86	71.86	
8			7-11	1,454	29.2		0.27	6.55	37.62	78.47	78.74	
9	Kennebec	Madison	1-4	3,200	100.0	31000	27.45	90.99	100.00	100.00	100.00	1.99
10			11+22	678	47.1		0.06	4.22	35.06	93.10	96.45	
11			3+4	762	52.0		0.	0.	18.80	92.23	97.13	
12		Augusta	1-8	5,470	100.0	154500	5.47	37.41	76.51	100.00	100.00	3.71
13			11+22	678	18.3		2.95	12.14	35.72	55.99	57.08	
14			3+4	762	20.5		1.30	7.79	29.62	57.94	61.85	
15			5	593	16.0		1.54	9.42	27.49	37.94	38.11	
16			6+8	727	19.6		0.16	1.27	11.49	36.61	36.61	
17			7	950	25.6		0.60	6.01	36.09	54.07	54.07	
18	Androscoggin	Livermore Falls	1-4	2,496	100.0	168700	10.90	36.14	71.66	98.50	100.00	4.85
19			11	1,045	72.0		4.05	4.05	4.05	4.05	4.05	
20			1	318	21.9		12.02	20.62	25.46	26.43	26.44	
21			11+1	1,363	93.9		21.02	21.13	21.13	21.13	21.13	
22			2	229	15.7		7.36	15.54	25.46	28.45	28.61	
23			1+2	547	37.6		20.21	37.41	42.74	44.46	44.46	
24			3	410	28.2		0.57	3.98	18.02	46.87	60.58	
25			4	494	34.0		0.	0.	4.66	25.18	41.18	
26		Gorham	1+11	1,363	100.0	223500	95.06	100.00	100.00	100.00	100.00	1.01
27		Auburn	1-6	3,257	100.0	199800	10.88	32.14	65.22	89.40	100.00	5.56
28			11	1,045	47.2		4.94	4.94	4.94	4.94	4.94	
29			11+1	1,363	61.6		4.66	4.69	4.69	4.69	4.69	
30			1+2	547	24.7		7.68	9.18	9.52	9.56	9.56	
31			3+4	904	40.8		6.44	17.68	39.26	62.20	71.51	
32			2-4	1,133	51.2		9.15	25.05	46.01	64.64	71.40	
33			5	345	15.5		0.	0.	2.97	16.79	25.79	
34			6	416	18.8		0.	0.02	4.25	20.59	29.29	

1/ Adjusted for existing storage in the basin.

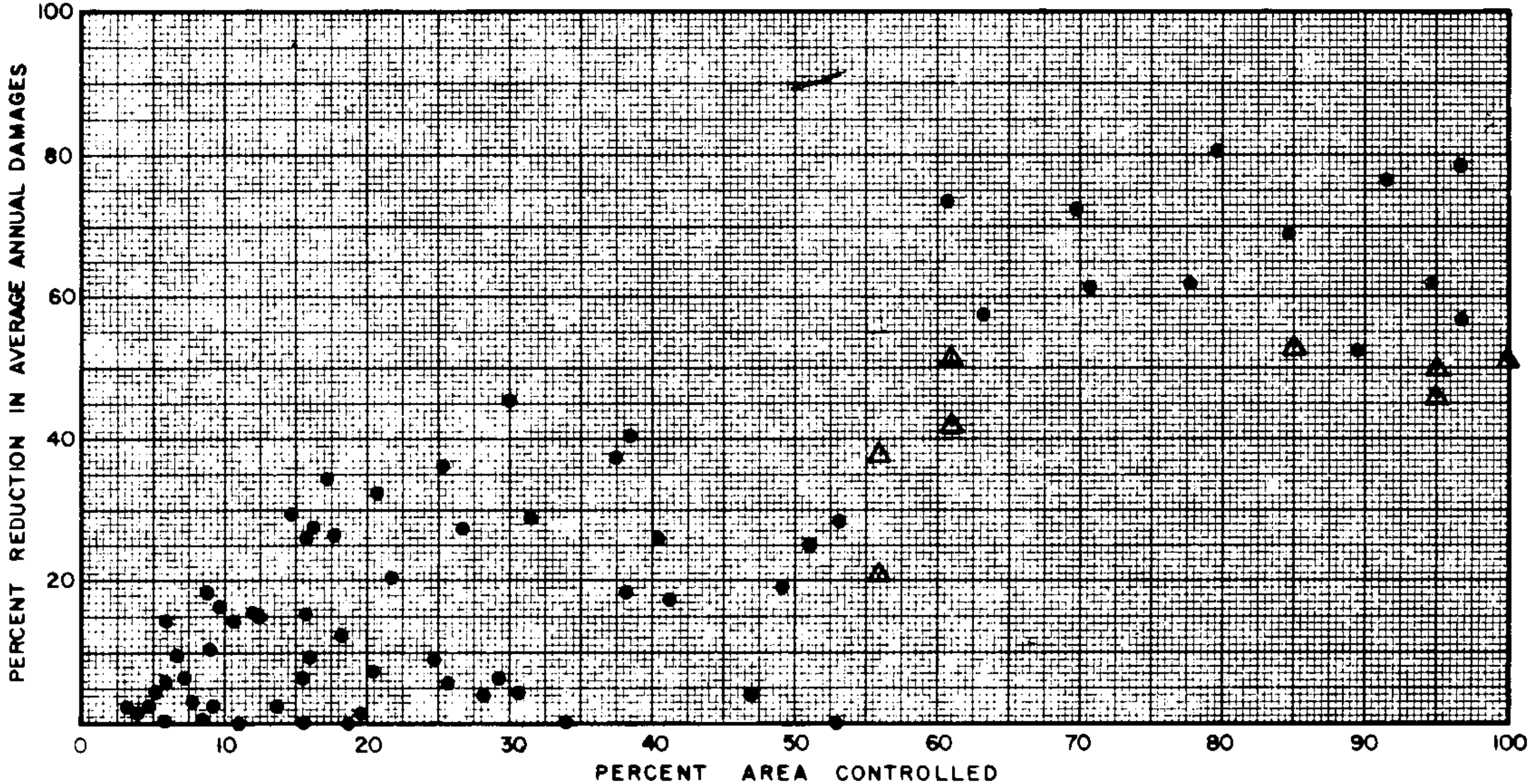
2/ To contain 200 yr. flood.

TABLE C-24 CONT.
SUMMARY OF REGULATORY EFFECTS OF FLOOD CONTROL STORAGE

No.	River Basin	Damage Center	Subareas Numbers (See Figure)	Drainage Area (Sq. Mi.)	Drainage[1/] Area Controlled (percent)	Average Annual Damages (Dollars)	Percent Average Annual Damage Reduction For Storage @ Dam Site of 0.5 inches	1.0 inches	2.0 inches	4.0[2/] inches	7.0[2/] inches	Maximum Storage Required[2/] (inches)
35	Saco	Hiram	1-4	843	100.0	125700	6.58	33.33	63.49	92.53	100.00	5.91
36		Biddleford	1-5	1,697	100.0	80500	8.12	35.01	74.27	98.96	100.00	4.25
37			1+2	843	59.9		39.20	55.45	61.38	61.38	61.38	
38			3	190	12.6		9.80	14.92	18.87	19.82	19.83	
39			4	265	17.6		3.47	8.84	24.07	37.70	40.77	
40			5	399	26.5		0.	0.	6.47	19.74	22.85	
41	Merrimack	Plymouth	1	621	100.0	77800	11.84	29.49	55.76	90.52	100.00	6.04
42		Lawrence	1-12	4,672	100.0	649700	53.21	70.60	97.56	100.00	100.00	2.45
43			1+2	1,000	38.8		14.79	15.30	15.30	15.30	15.30	
44			444	471	18.3		0.59	0.59	0.59	0.59	0.59	
45			66+3	626	24.3		4.07	4.09	4.09	4.09	4.09	
46			4	230	08.9		14.33	18.75	22.58	25.05	25.19	
47			5	150	05.8		8.15	14.91	19.16	21.35	22.71	
48			4+5	380	14.8		16.76	29.83	36.06	40.41	40.82	
49			7	652	25.3		28.66	36.80	43.14	46.30	46.30	
50			8	171	06.6		2.68	9.05	18.76	22.28	25.14	
51			666+8	323	12.5		3.97	15.22	29.67	36.78	40.52	
52			9	530	20.6		24.10	32.64	38.78	41.25	41.25	
53			10	406	15.8		16.89	26.01	31.28	35.44	35.44	
54			10-12	690	26.8		0.	27.45	33.99	46.16	46.16	
55			11+12	284	11.0		0.	0.	15.14	17.31	21.85	
56	Connecticut	Dalton	1	1,514	100.0	58100	22.71	57.77	91.64	100.00	100.00	2.75
57		South Newberry	1-4	2,851	100.0	110900	27.46	57.60	88.57	100.00	100.00	3.01
58			1	1,514	53.1		27.84	28.03	28.03	28.03	28.03	
59			2	507	17.8		11.74	26.28	49.73	65.96	70.49	
60			1+2	2,021	70.9		46.96	61.54	69.57	69.57	69.57	
61			3	395	13.9		0.	2.81	23.06	40.64	46.74	
62			1-3	2,416	84.7		41.91	68.87	89.09	94.80	94.80	
63			4	435	15.3		0.	6.16	25.33	39.61	41.73	
64	Mohawk	Schenectady	1-5	3,306	100.0	294700	45.28	75.19	93.66	100.00	100.00	2.95
65	Rappahannock	Fredricksburg	1	1,599	100.0	152000	1.30	3.75	13.33	99.38	100.00	4.45
66	James	Holcombs Rock	1	3,250	100.0	124000	11.23	51.76	100.00	100.00	100.00	1.93
67		Richmond	1-2	6,757	100.0	964000	6.44	28.30	92.87	100.00	100.00	2.29

TABLE C-24 CONT.
SUMMARY OF REGULATORY EFFECTS OF FLOOD CONTROL STORAGE

No.	River Basin	Damage Center	Subareas Numbers (See Figure)	Drainage Area (Sq. Mi.)	Drainage[1/] Area Controlled (percent)	Average Annual Damages (Dollars)	Percent Average Annual Damage Reduction For Storage @ Dam Site of 0.5 inches	1.0 inches	2.0 inches	4.0[2/] inches	7.0[2/] inches	Maximum Storage Required[2/] (inches)
68	Connecticut	North Hampton	1-17	8,284	100.0	331800	19.49	50.40	85.40	100.00	100.00	3.26
69			1-4	2,851	40.3		25.09	26.19	26.25	26.25	26.25	
70			5	690	09.8		8.26	16.53	27.46	32.80	33.11	
71			6+7	772	10.9		6.91	14.18	25.97	33.83	34.48	
72			1-8	4,507	63.7		44.88	57.60	61.03	61.03	61.03	
73			10	269	03.8		0.19	1.20	5.26	8.98	10.97	
74			11	863	12.2		6.54	15.12	25.91	28.31	28.31	
75			1-111	5,493	77.7		41.45	62.23	72.72	73.89	73.89	
76			12	423	06.0		1.26	2.24	2.59	2.59	2.59	
77			13	420	05.9		0.	0.	1.41	4.77	6.52	
78			1-13	6,686	94.6		34.33	62.00	79.62	86.01	86.01	
79			14+17	542	07.7		0.	3.16	5.75	10.50	11.72	
80			15	664	09.4		0.	0.	2.35	7.45	11.02	
81			16	392	05.5		1.66	3.59	5.55	6.03	6.03	
82			1-14, 16	6,836	96.7		26.75	57.89	80.52	89.98	89.98	
83			1-5,7-10,12,13,15,16	6,328	89.5		25.19	52.41	76.32	86.09	86.09	
84			5,7-10,12,13, 15,16	3,477	49.2		3.77	19.19	46.14	63.14	63.14	
85		Middletown	1-21	10,870	100.0	123500	17.91	48.04	88.64	100.00	100.00	2.62
86			1-4	2,851	31.5		23.55	29.11	30.64	30.68	30.68	
87			5-7	1,462	16.2		15.08	27.67	43.46	50.45	50.50	
88			1-111	5,493	60.7		52.59	73.68	76.57	76.57	76.57	
89			10-12	1,555	17.2		14.34	27.13	37.84	40.42	40.42	
90			1-13	6,686	73.9		56.16	79.25	86.29	86.29	86.29	
91			1-14,16	7,201	79.6		62.99	80.45	86.37	86.37	86.37	
92			1-5,7-10,12,13,15,16	6,328	69.9		45.61	72.62	88.27	88.27	88.27	
93			5,7-10,12,13,15,16	3,477	38.4		19.37	40.36	68.22	82.55	82.55	
94			13,16	812	09.0		4.30	10.61	19.57	24.62	24.63	
95			15	664	07.3		1.06	6.61	12.96	21.79	25.80	
96			1-17	8,284	91.5		50.06	76.80	95.26	97.64	97.64	
97			14+17	542	06.0		1.96	5.95	11.93	16.40	16.89	
98			18	472	05.2		0.62	4.02	7.93	9.48	9.48	
99			1-18	8,756	96.7		49.26	78.38	96.83	99.15	99.15	
100			19	301	03.3		0.20	2.42	4.81	6.29	6.29	
101			20	443	04.9		0.21	2.41	6.18	9.81	9.89	
102			21	764	08.4		0.	0.22	2.56	8.46	9.37	
103	Housatonic	Great Barrington	1-2	280	100.0	106500	17.53	46.35	81.64	100.00	100.00	2.46
104			1	130	46.4		31.86	48.12	62.18	65.66	65.66	
105			2	150	53.6		10.81	33.60	63.50	75.04	75.04	
106		Gaylordsville	1-4	994	100.0	39500	8.51	15.68	42.70	82.72	100.00	4.41
107			1+2	280	28.2		13.06	23.80	35.92	42.65	42.86	
108			3	352	35.4		9.89	24.41	43.04	55.90	55.90	
109			4	362	36.4		0.99	4.75	10.44	37.20	67.53	



LEGEND

● Data from current study

△ Data from planning and design reports in region

PERCENT DAMAGE REDUCTION FOR 1 INCH OF STORAGE

FIGURE C-19

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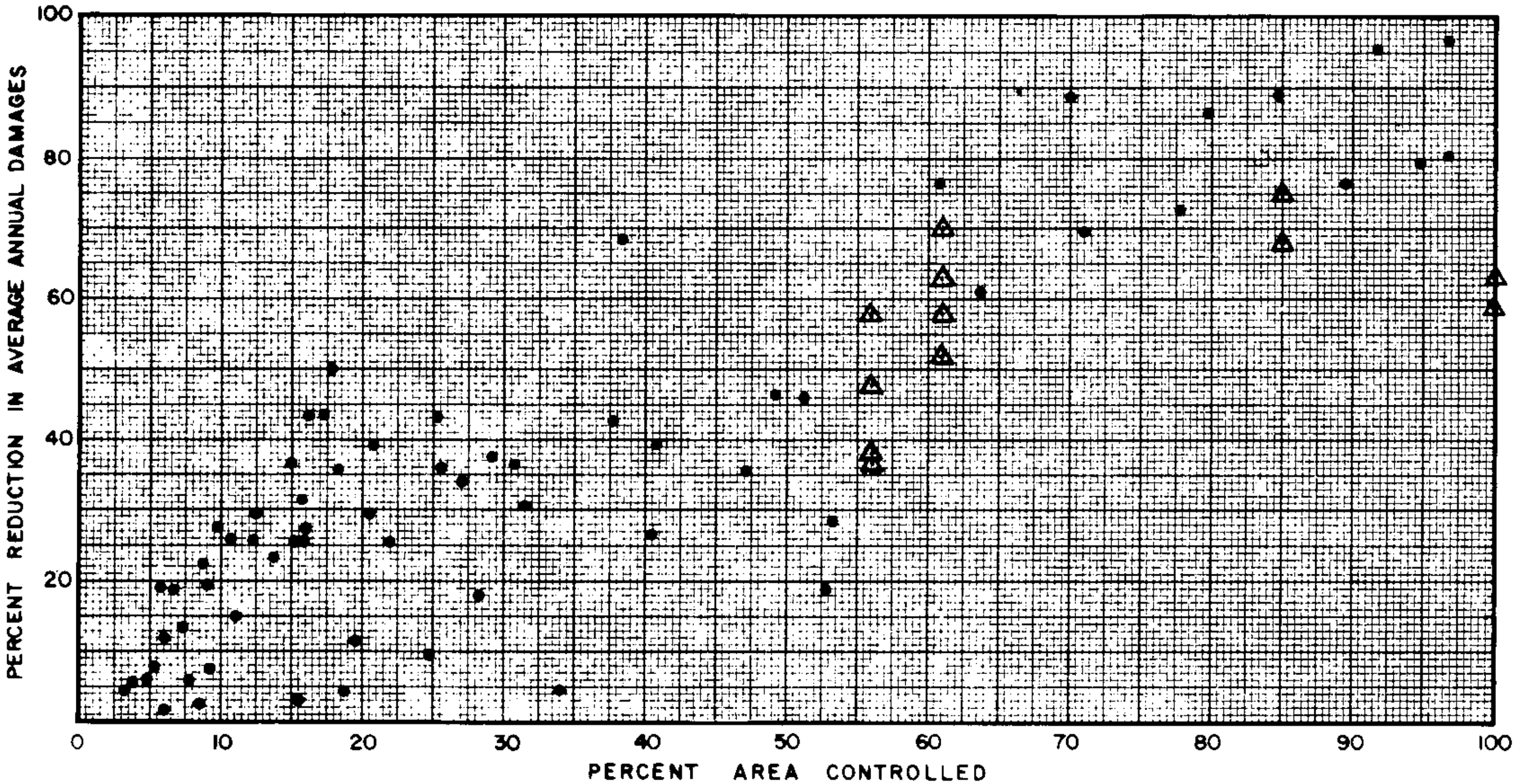

LEGEND

● Data from current study

△ Data from planning and design reports in region

PERCENT DAMAGE REDUCTION FOR 2 INCHES OF STORAGE

FIGURE C-20

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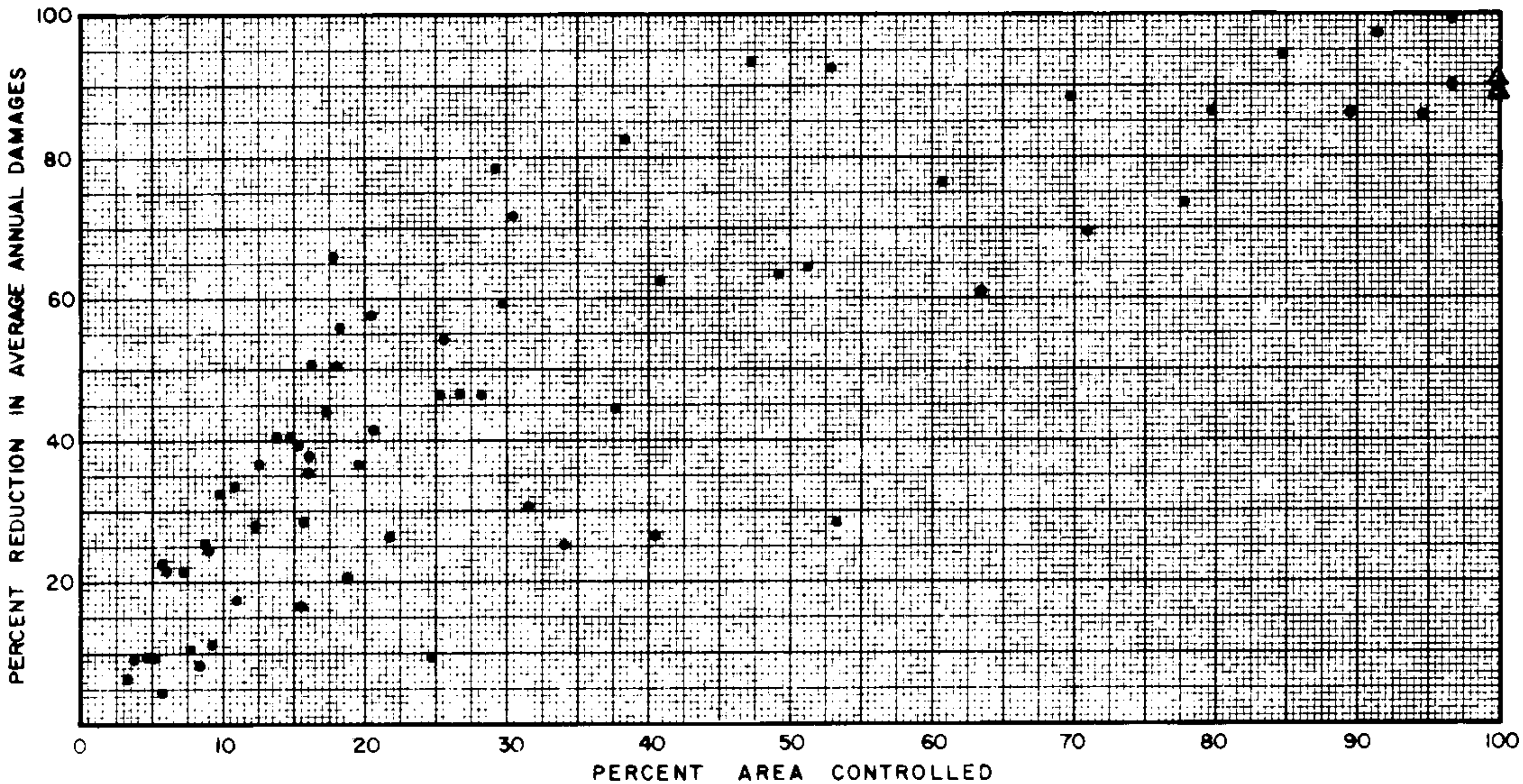


LEGEND

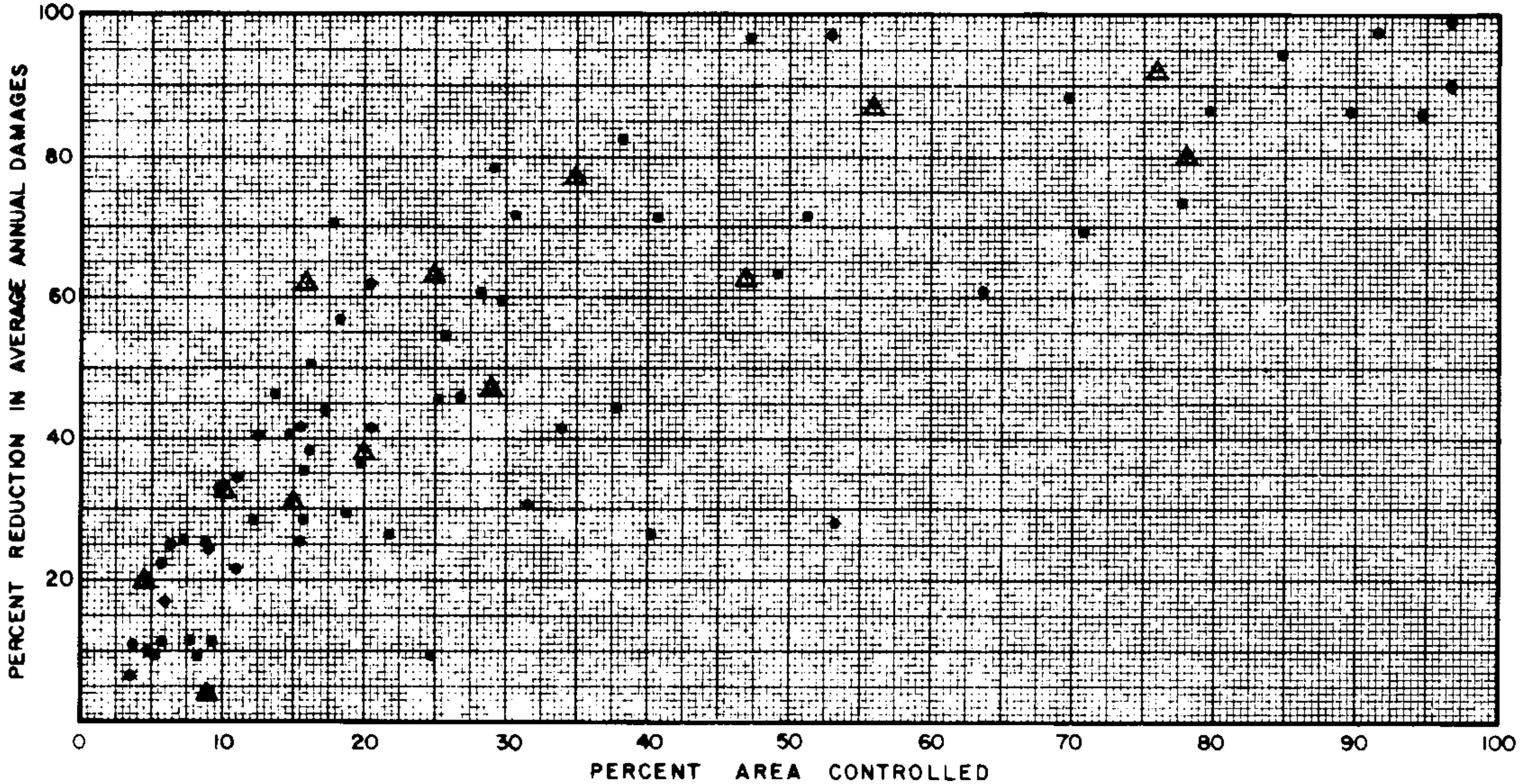
● Data from current study

△ Data from planning and design reports in region

PERCENT DAMAGE
REDUCTION
FOR
4 INCHES OF STORAGE

FIGURE C-21

The Hydrologic Engineering Center



LEGEND

- ● Data from current study
- △ Data from planning and design reports in region

PERCENT DAMAGE REDUCTION FOR 6 INCHES OF STORAGE

FIGURE C-22

The Hydrologic Engineering Center

regulatory effects of flood control storage are shown in Table C-24. The results for partial area control are also illustrated by the data plotted on Figures C-19 through C-22, which show the relationship between percent damage reduction and percent area controlled for 1, 2, 4 and 6 inches of flood control storage. Although a value of 7 inches of flood control storage was used in the operation studies, it was found that an average of about 6 inches was required to contain the largest flood evaluated, which corresponds to the midpoint of the frequency range of zero to one percent (See Table C-23).

Although the scatter in the results was considerable, there is a definite relation between percent area controlled and damage reduction. This scatter would also prevail if detailed system operation studies were made. This is illustrated by the results of prior studies listed in Table C-25, and plotted on Figures C-19 through C-22.

MULTIPLE REGRESSION ANALYSIS

A multiple regression analysis was made correlating basin characteristics such as slope, drainage area and length; hydrologic characteristics such as normal annual precipitation, peak frequency and volume; and flood damage data with "percent reduction in average annual damages." The most significant independent variable was "percent area controlled". Improvement resulted in the correlation by using a relative timing factor which accounted for the location of a sub-basin in relation to the total basin area. The factor is defined as follows:

$$\text{RTF} = \text{absolute value of } 1 - \frac{0.6\ L_p + L}{0.6\ L_T}$$

in which:

RTF = Relative timing factor
L_p = Length of longest watercourse for the sub-basin
L_T = Length of longest watercourse for the total area
L = Length of watercourse between lower end of Sub-basin (impoundment site) and lower end of total area (control point location)

The use of the variable, relative timing factor, as the second independent variable in the multiple regression analysis increased the adjusted determination coefficient ($\bar{R}^2$) an average of about 5%. For example, the $\bar{R}^2$ for two inches of flood control storage was increased from .663 to .718 when the relative timing factor was included. For four inches of flood control storage the increase was from .733 to .824. It is logical that runoff from Sub-basins near the damage center and remotely upstream does not contribute to peak flows as effectively as

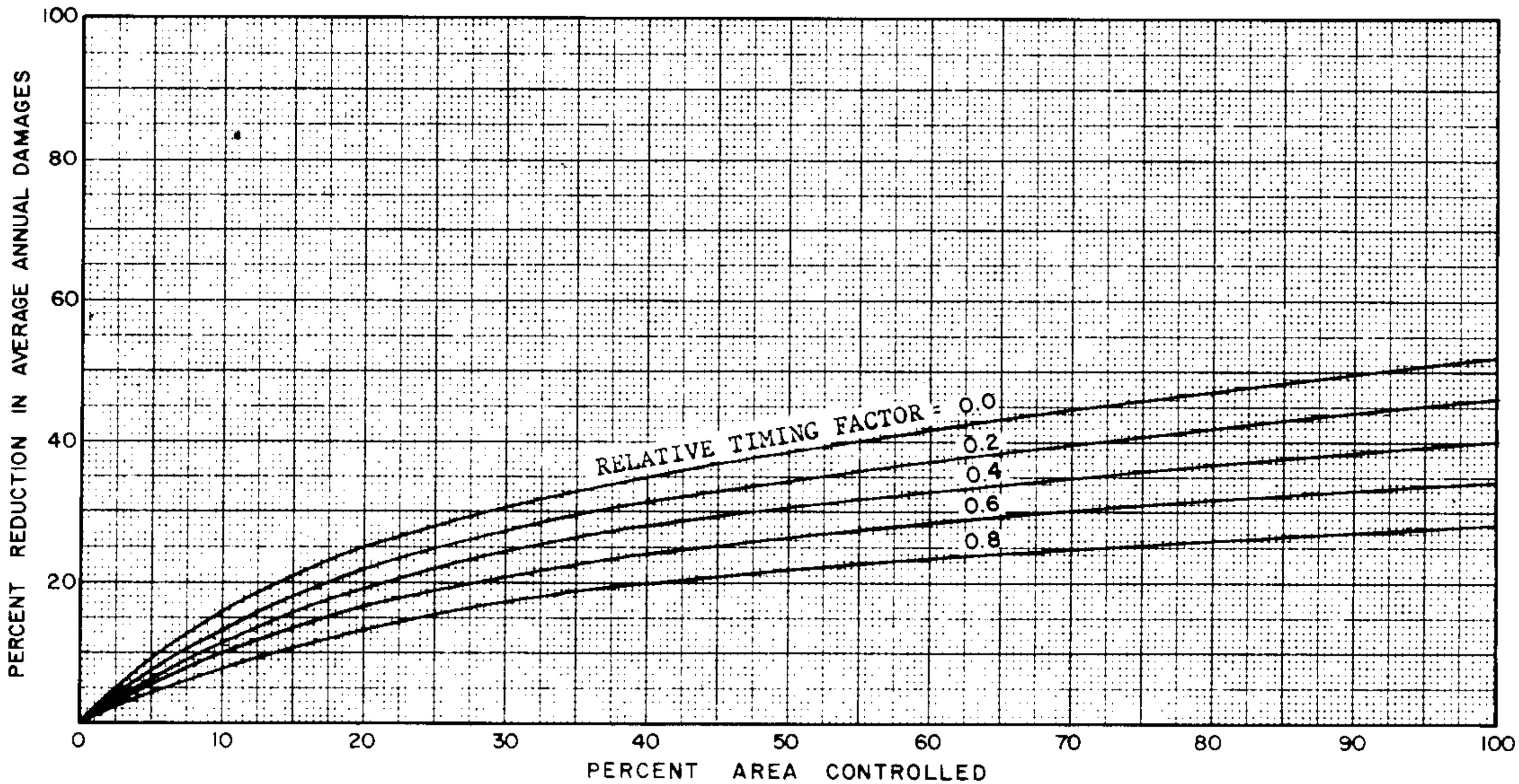
TABLE C-25
DATA ON DAMAGE REDUCTION FROM PARTIAL AREA CONTROL
(Extracted from planning and design reports)

River Basin	Reservoir Project	Percent Area Controlled	Inches of Storage	Relative Timing Factor	Percent Damage Reduction
Rappahannock	Salem Church	100	3.5	0	89
James	Gathright	78	8.0	.35	80
	"	56	8.0	.35	87
	"	25	8.0	.32	63
	"	16	8.0	.42	62
	"	10	8.0	.47	33
Susquehanna	Raystown	47	6.0	.05	63
	"	35	6.0	.19	77
	"	29	6.0	.27	47
	"	4	6.0	.02	20
	Curwensville	76	6.0	.06	92
Delaware	Blue Marsh	20	6.0	.21	38
	"	15	6.0	.15	31
	"	9	6.0	.33	4
	Tocks Island	100	0.9	0	51
	"	85	0.9	.06	53
	"	61	0.9	.10	51
	"	61	0.9	.10	42
	"	56	0.9	.19	38
	"	56	0.9	.22	21
	"	100	1.9	0	59
	"	85	1.9	.06	68
	"	61	1.9	.10	63
	"	61	1.9	.10	52
	"	56	1.9	.19	48
	"	56	1.9	.22	37
	"	100	2.3	0	63
	"	85	2.3	.06	75
	"	61	2.3	.10	70
	"	61	2.3	.10	58
	"	56	2.3	.19	58
	"	56	2.3	.22	37
Potomac	Seneca	95	1.1	.03	46
	Riverbank	95	1.2	.02	50
	Royal Glen	100	3.2	0	91

does runoff from the middle tributaries. Therefore, it was concluded that the generalized relationships to be adopted for computing reductions in average annual damages should be based on results using these two variables.

GENERALIZED RESULTS

The generalized relationships adopted for estimating reductions in average annual damages for 1, 2, 4 and 6 inches of flood control storage are presented on Figures C-23 through C-26 and generalized curves for a relative timing factor of zero are presented on Figure C-27. These adopted relationships were derived from the results of the multiple regression analysis with appropriate adjustments to assure consistency and conformity within the different sets of generalized curves. Instructions and guidance on the use of these generalized relationships for estimating reductions in flood damages are described in Appendix E.



$$RTF = \text{absolute value of } 1 - \frac{0.6L_P + L}{0.6L_T}$$

where: RTF = Relative Timing factor

L_P = Length of longest watercourse for the subarea

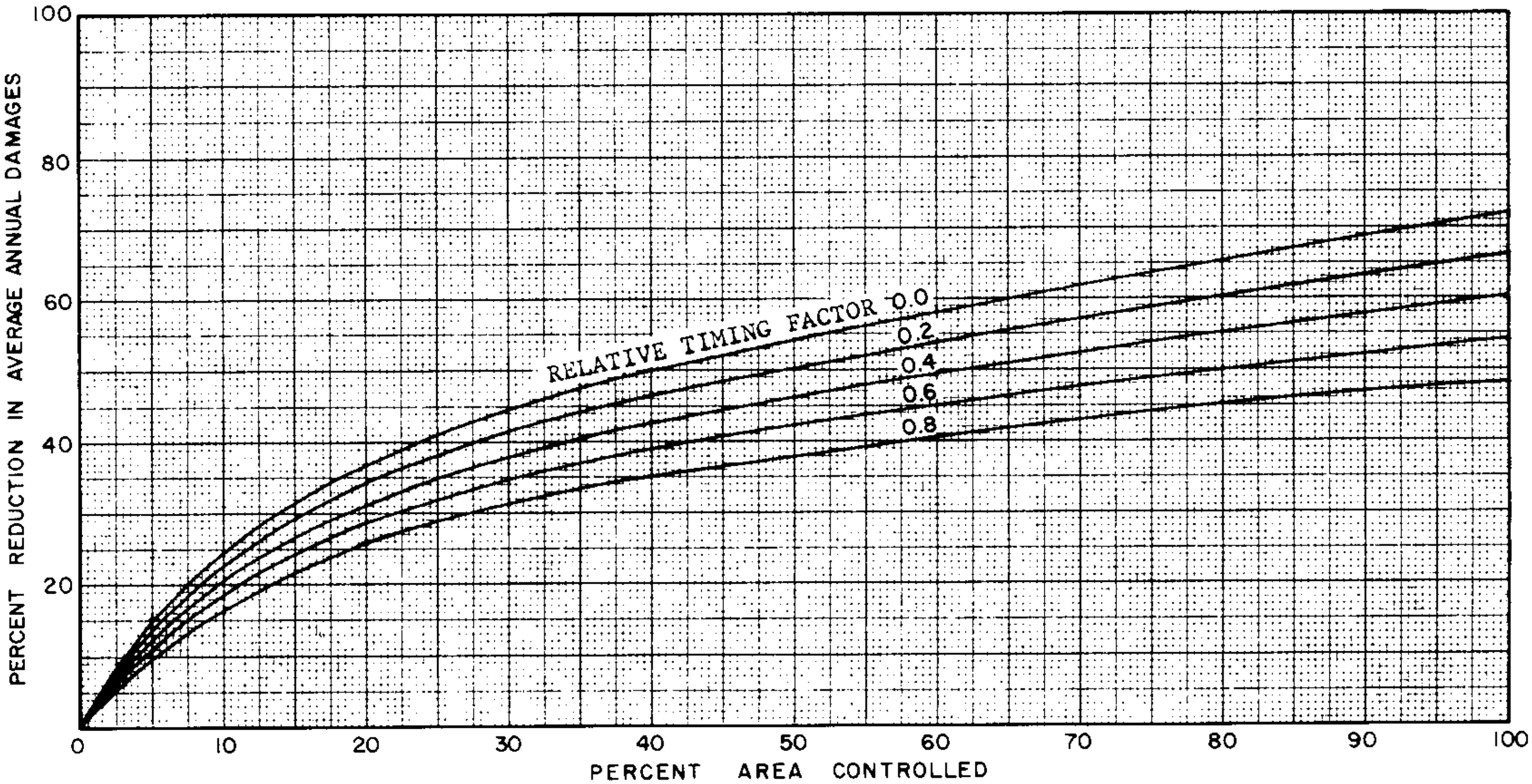
L_T = Length of longest watercourse for the total area

L = Length of watercourse between the subarea outlet and the total area outlet

PERCENT DAMAGE
REDUCTION
FOR
1 INCH OF STORAGE
WITH RELATIVE TIMING FACTORS

FIGURE C-23

The Hydrologic Engineering Center



$$RTF = \text{absolute value of } 1 - \frac{0.6L_P+L}{0.6L_T}$$

where: RTF = Relative Timing factor

L_P = Length of longest watercourse for the subarea

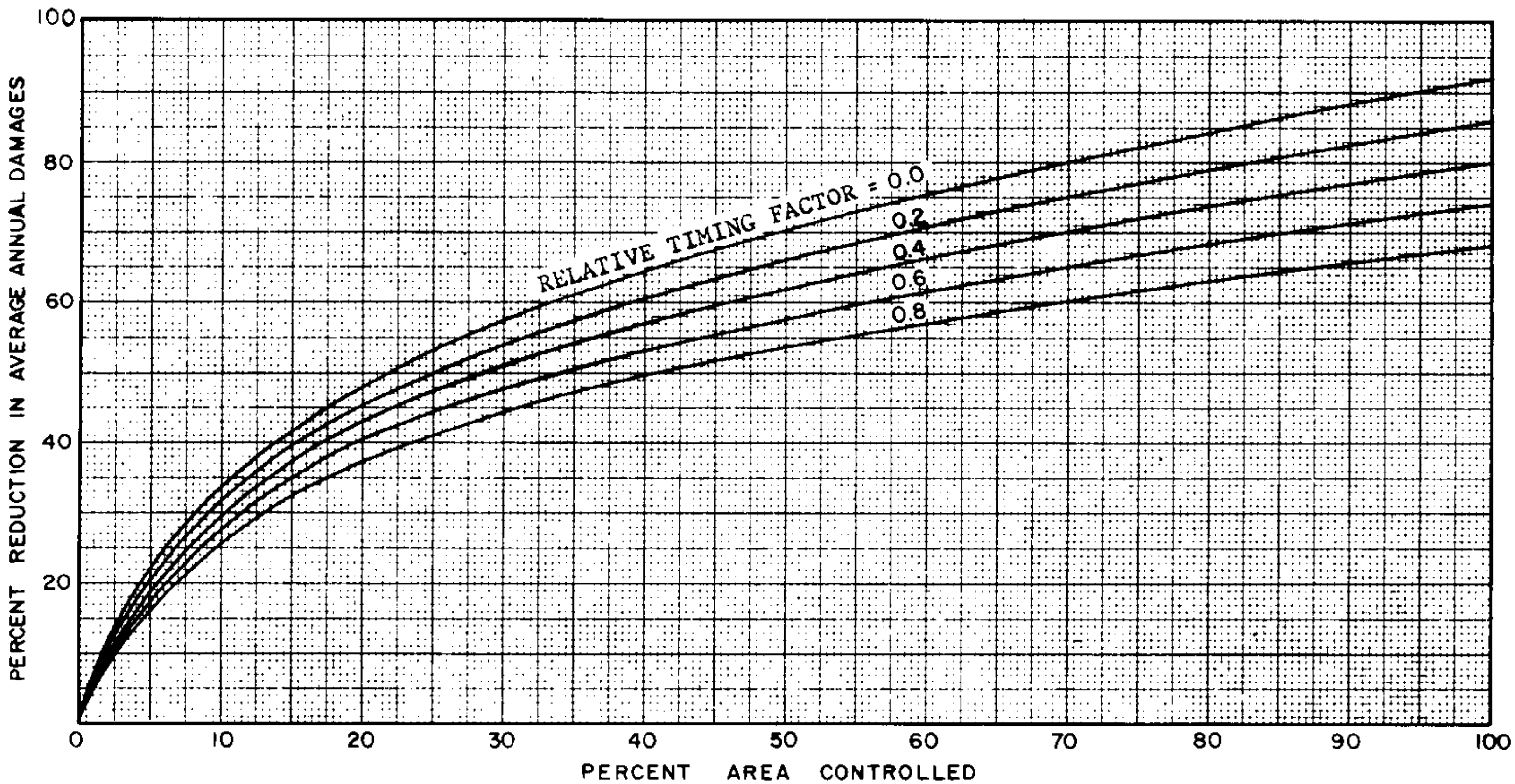
L_T = Length of longest watercourse for the total area

L = Length of watercourse between the subarea outlet and the total area outlet

PERCENT DAMAGE
REDUCTION
FOR
2 INCHES OF STORAGE
WITH RELATIVE TIMING FACTORS

FIGURE C-24

The Hydrologic Engineering Center



$$RTF = \text{absolute value of } 1 - \frac{0.6L_P + L}{0.6L_T}$$

where: RTF = Relative Timing factor

L_P = Length of longest watercourse for the subarea

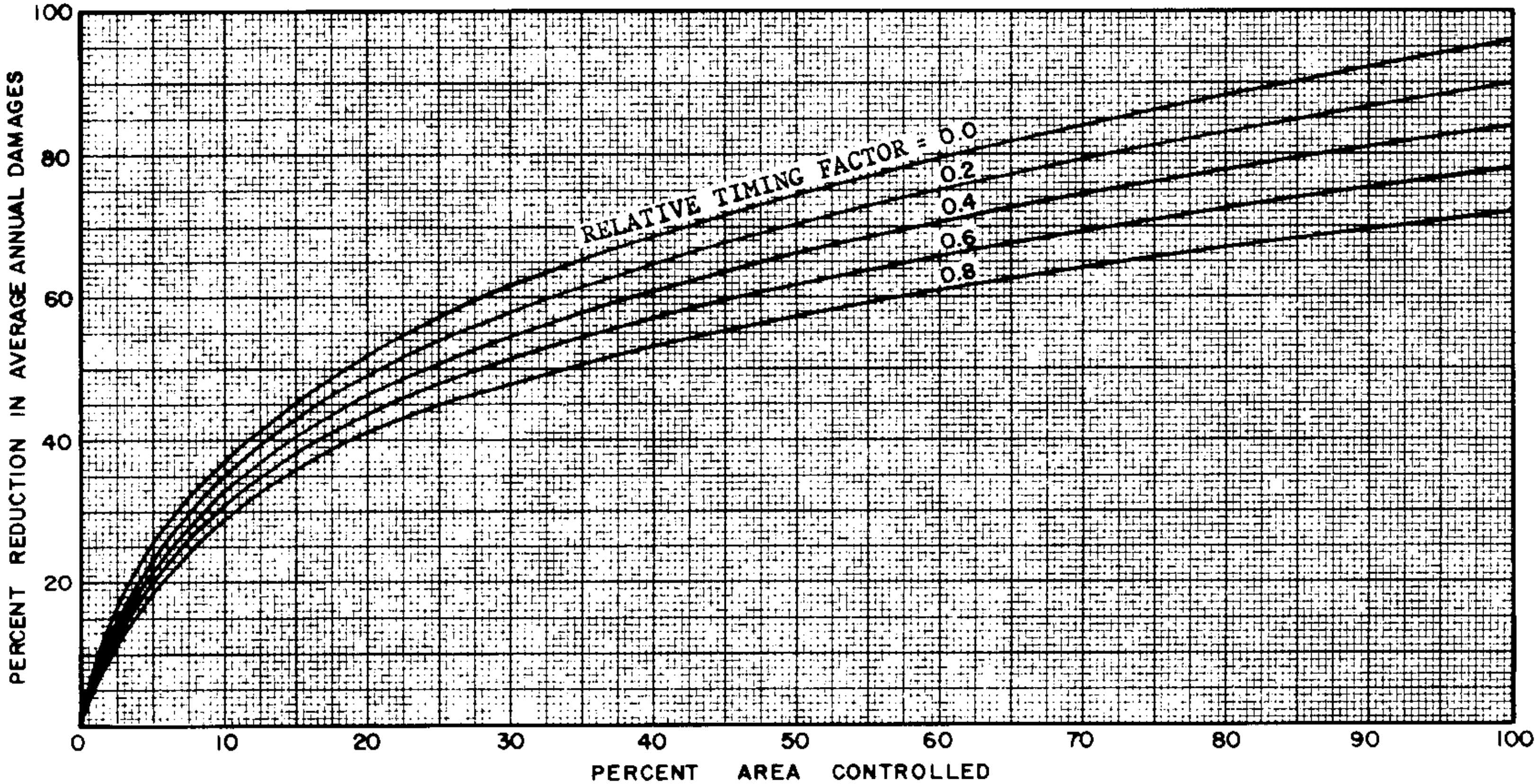
L_T = Length of longest watercourse for the total area

L = Length of watercourse between the subarea outlet and the total area outlet

PERCENT DAMAGE REDUCTION FOR 4 INCHES OF STORAGE WITH RELATIVE TIMING FACTORS

FIGURE C-25

The Hydrologic Engineering Center



$$RTF = \text{absolute value of } 1 - \frac{0.6L_p+L}{0.6L_T}$$

where: RTF = Relative Timing factor

L_p = Length of longest watercourse for the subarea

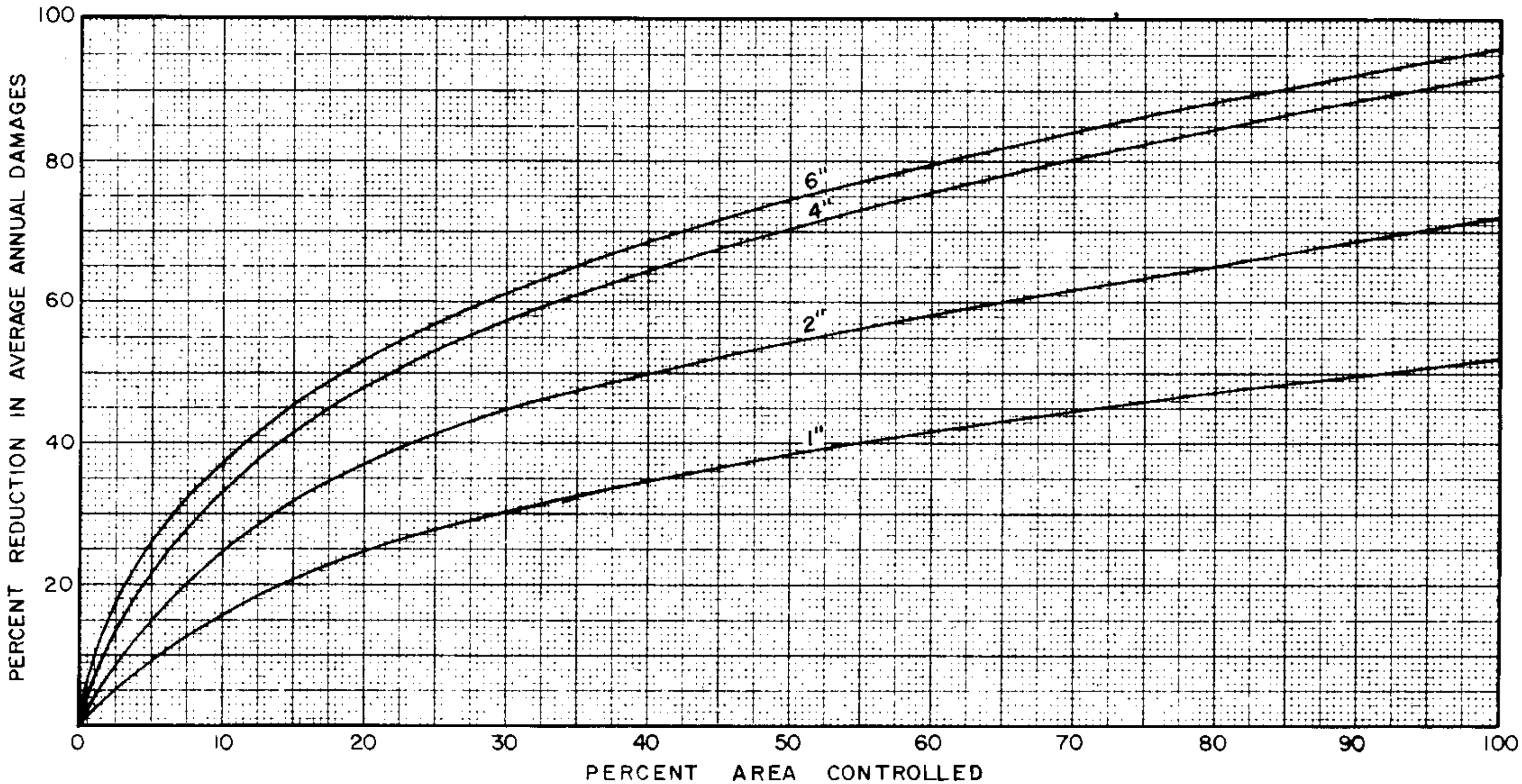
L_T = Length of longest watercourse for the total area

L = Length of watercourse between the subarea outlet and the total area outlet

PERCENT DAMAGE REDUCTION FOR 6 INCHES OF STORAGE WITH RELATIVE TIMING FACTORS

FIGURE C-26

The Hydrologic Engineering Center



$$\text{RTF} = \text{absolute value of } 1 - \frac{0.6L_P+L}{0.6L_T}$$

where: RTF = Relative Timing factor

L_P = Length of longest watercourse for the subarea

L_T = Length of longest watercourse for the total area

L = Length of watercourse between the subarea outlet and the total area outlet

PERCENT DAMAGE REDUCTION FOR RELATIVE TIMING FACTOR OF ZERO

FIGURE C-27

The Hydrologic Engineering Center

CHAPTER 4. SUB-REGIONAL SUMMARIES

SUB-REGION A

Sub-region A lies in the northeast corner of the NAR and includes four major river basins, the St. John, Penobscot, Kennebec and Androscoggin, and the coastal area of most of the State of Maine. Figure C-1 shows the Areas and Sub-areas of the Sub-region.

The Sub-regions's average annual precipitation is about 41 inches, distributed relatively uniformly throughout the year. Winters in the northern part are severe, with more than 100 inches of snow in some places. Average annual lake evaporation ranges, north to south, from 20 to 24 inches.

The average annual temperature varies from 38° F. in the northern headwaters to about 45° F. along the coast. The length of the growing season varies from about 160 days in areas along the coast to less than 100 days inland. The average relative humidity in July ranges from 65% to 70%, which is somewhat higher than in the remainder of the North Atlantic Region.

Average wind velocities are from 8 to 10 m.p.h., with mostly northerly and northwesterly winds during the winter and southerly winds prevailing during the summer.

Sub-region A's average annual runoff is approximately 23.5 inches, or slightly more than half of the precipitation. Much of the overland runoff occurs during the late winter and early spring, as a result of a combination of snowmelt, precipitation and a relative lack of vegetative covering. However, a large amount of natural surface storage provided by lakes tends to moderate extremes in flow patterns.

Flooding occurs almost annually as a result of heavy spring rains combining with snowmelt and ice-breakup, causing particular problems in the Penobscot, Kennebec and Androscoggin Basins. Low flows are modified by the effects of natural and man-made storage and are generally not as extreme as in some other parts of the NAR. The Sub-region's existing minimum seven-day flow is equivalent to about 0.31 c.s.m.(Shortage Index 0.01).

Surface water quality is generally good, with low to moderate mineral content and a hardness of less than 50 p.p.m. in most places. Local poor water quality and occasional pollution problems are encountered in ground water supplies, but the overall quality is generally good. There are many productive aquifers in glacial outwash, and some in the consolidated rocks.

The shorelines of Sub-region A is very irregular, with an estimated length of about 2,500 miles. Tidal ranges are very high along the coast, ranging up to 19 feet at the mouth of the St. Croix River.

CLIMATE AND METEOROLOGY

Meteorologic Records

The number of meteorologic stations, although not as plentiful as in other Sub-regions, is well distributed and presents a satisfactory description of the Sub-regional climate. Moreover, many records are of long duration. The principal source of data is the National Weather Service. Figure C-28 shows the locations of some of the available meteorologic data stations in this Sub-region.

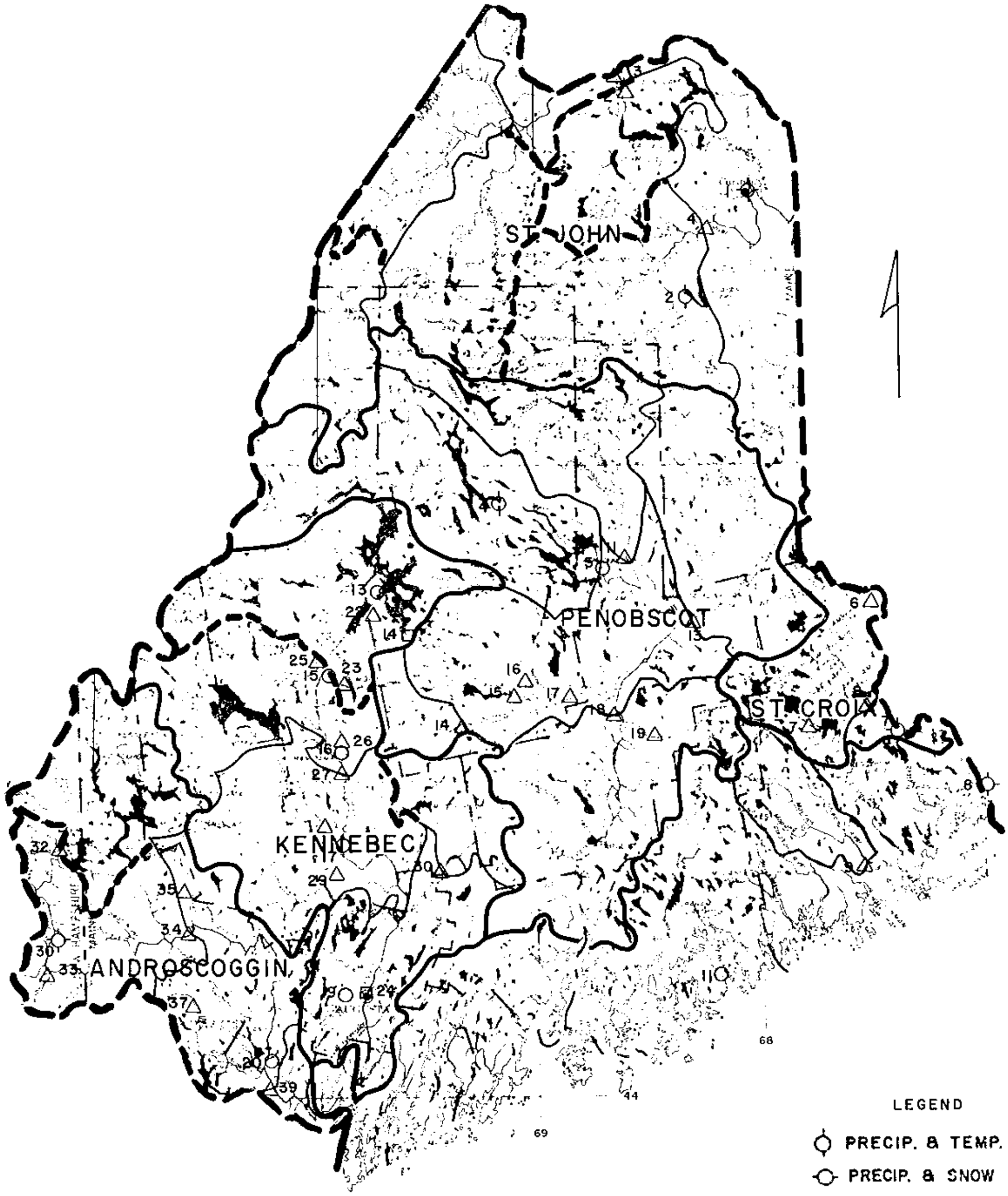
Precipitation

Sub-region A lies in the belt of prevailing wasterlies, and the cyclonic disturbances that cross the continent in this movement bring frequent, although relatively short, periods of precipitation. Occasional coastal storms, or northeasterns, some of tropical origin, may be heavily laden with moisture when they reach the Sub-region, although their original violence is often diminished. Thunderstorm activity causes brief and usually localized heavy rainfall during the summer months, particularly in the interior and northern portions of the Sub-region.

The average annual precipitation is about 41 inches. As illustrated on Figure C-3 (p. C-7), there is a sharp increase to slightly over 50 inches in some of the mountainous areas along the Maine-New Hampshire border, and also a band of above average precipitation along the Atlantic Coast.

Precipitation is distributed rather uniformly throughout the year, as shown in Table C-26. However, it has been noted that precipitation in the summer months along the coast tends to be somewhat less than during winter months. The reverse is true in northern inland areas, because of increased thunderstorm activity and the lesser effects of the winter coastal storms.

As shown in Figure C-4 (p. C-9), average annual snowfall varies from 60 to 70 inches in coastal areas to more than 100 inches inland. Variations in topography cause large snowfall variations within a few miles. Monthly variations in snowfall at selected stations are illustrated in Table C-27. Most of the snowfall occurs in January and February, and indications are that practically all of the Sub-region's precipitation could be in the



LEGEND

PRECIP. & TEMP.

PRECIP. & SNOW

PRECIP., TEMP. & SNOW

SNOW

STREAMFLOW STATIONS

FIGURE C-28

METEOROLOGIC AND STREAMFLOW STATIONS

SUBREGION A

10 0 10 20 30 40

SCALE IN MILES

10 0 10 20 30 40 Miles

SCALE

TABLE C-26

PRECIPITATION DATA -SUBREGION A(in inches)

Station	Map Code	Period of Record	Elevation ft.,m.s.l.	Item	Monthly Data (a) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Annual (a)
Caribou,Me.	1	1937-65	624	Max	3.59	4.13	5.13	4.50	6.27	7.11	6.83	8.45	8.14	6.20	6.53	5.01	36.31
				Min	.12	1.14	1.11	.86	.64	1.70	1.97	.93	1.26	.63	.45	.79	
				Mean	2.11	2.02	2.38	2.63	3.03	4.07	4.04	3.67	3.53	3.36	3.04	2.43	
Squa Pan Dam,Me.	2	1931-60	610	Mean	2.52	2.33	2.57	2.87	2.89	4.06	3.71	3.38	3.46	3.42	3.34	2.68	37.23
Ripogenus Dam,Me.	4	1931-60	965	Mean	2.62	2.47	2.81	3.46	3.36	4.28	4.20	3.84	3.77	3.95	3.75	2.89	41.40
Millinocket,Me.	5	1931-60	388	Mean	3.24	2.84	3.22	3.44	3.12	3.89	3.47	3.73	3.67	3.72	4.11	3.50	41.95
Moosehead,Me.	13	1931-60	1,028	Mean	2.57	2.27	2.80	3.09	2.96	3.78	4.05	3.52	3.31	3.52	3.47	2.85	38.19
The Forks,Me.	15	1931-60	610	Mean	2.76	2.32	2.83	3.00	2.97	3.57	3.46	3.13	3.26	3.39	3.45	2.78	36.92
Woodland,Me.	7	1931-61	140	Max	9.03	7.19	7.78	6.49	7.25	8.14	7.10	6.92	9.08	8.17	12.61	7.87	43.94
				Min	.54	1.03	1.74	.63	.67	1.05	.74	.56	.97	.57	1.06	.96	
				Mean	3.71	3.20	3.47	3.57	3.46	3.42	3.23	2.95	3.82	4.29	4.82	4.00	
Eastport,Me.	8	1873-1961	80	Max	9.23	6.85	7.42	6.35	8.18	7.95	5.37	6.61	7.65	6.37	8.57	8.40	42.67
				Min	.56	.40	1.37	.46	.75	.52	.75	.64	.92	.19	.94	1.07	
				Mean	4.11	3.44	3.68	3.50	3.09	3.55	3.07	2.86	3.53	3.62	4.48	3.74	
Madison,Me.	17	1931-60	260	Mean	3.29	2.83	3.28	3.30	3.23	3.33	3.18	2.63	3.45	3.20	3.92	3.28	38.92
Bar Harbor,Me.	11	1931-60	30	Mean	4.46	3.79	4.39	3.91	3.83	3.34	3.10	3.12	4.22	4.38	5.25	4.38	48.17
Berlin,N.H.	30	1917-60	1,110	Max	7.15	4.01	10.46	6.05	6.58	7.50	6.08	6.96	12.26	7.40	8.11	5.79	38.44
				Min	.78	.89	.75	.47	1.12	1.63	1.18	.74	.62	.46	.73	.89	
				Mean	2.92	2.32	3.15	2.94	3.18	3.94	3.61	3.02	3.85	3.12	3.46	2.93	
East Winthrop,Me.	19	1931-61	173	Max	7.85	6.90	9.59	6.91	7.51	6.36	7.24	5.86	10.77	7.44	7.22	7.33	41.70
				Min	1.13	1.07	1.02	0.60	0.68	0.97	0.34	0.64	0.55	0.16	0.56	0.93	
				Mean	3.57	3.09	3.58	3.51	3.33	3.16	3.41	2.85	3.94	3.40	4.26	3.60	
Lewiston,Me.	20	1931-60	180	Mean	4.01	3.37	4.13	3.78	3.33	3.23	3.39	2.76	3.65	3.51	4.46	3.96	43.58

(a) Data based on 30-year period 1931-60 except for station 1 where period of record is used.

TABLE C-27

SNOW DATA - SUBREGION A

Station	Map Code	Years of Record	Elevation ft.,m.s.l.	Average Snowfall in Inches (a) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Caribou,Me.	1	26	624	22.1	23.9	19.4	7.5	0.3	T	0	0	T	2.7	11.7	19.6	107.2
Squa Pan Dam,Me.	2	22	610	22.6	24.2	21.3	7.9	0.3	0	T	0	T	1.3	9.8	19.5	106.9
Ripogenus Dam,Me.	4	23-25	965	24.7	23.2	20.9	9.6	0.6	0	0	0	T	1.2	9.2	19.7	109.1
Woodland,Me.	7	31(1931-61)	140	20.3	20.0	15.3	4.6	0.2	0	0	0	0	0.4	5.1	14.2	80.1
Eastport,Me.	8	30(1931-60)	80	18.0	18.0	12.7	4.4	T	0	0	0	0	0.1	3.0	10.7	66.9
Greenville,Me.	14	48	1061	24.4	23.1	20.3	10.2	0.7	0	T	T	T	1.6	10.6	20.1	111.0
Madison,Me.	17	26	260	22.1	19.5	13.7	4.5	0.3	T	0	0	T	0.3	6.3	13.9	80.6
East Winthrop,Me.	19	31(1931-61)	173	19.8	18.2	14.6	4.5	0.4	0	0	0	0	T	4.8	12.1	74.4
Augusta,Me.	24	16	350	21.9	22.0	13.4	2.2	0.8	0	0	0	0	T	3.7	13.0	77.0
Berlin,N.H.	30	30(1931-60)	1110	21.9	20.9	22.2	6.5	0.5	T	0	0	T	1.0	9.5	16.7	99.2

(a) Data based on years of record indicated in the third column.

TABLE C-28

TEMPERATURE DATA -SUBREGION A (in degrees Fahrenheit)

Station	Map Code	Period of Record	Elevation ft.,m.s.l.	Mean Annual Temperature (a)			Mean Monthly Temperature (a) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				Max.Year	41.1	Max.Month	21.4	22.9	31.8	41.9	57.1	62.8	69.6	67.2	57.5	48.8	36.5	22.4
Caribou,Me.	1	1937-65	624	Min.Year	36.3	Min.Month	1.3	4.7	15.2	29.1	43.7	54.5	61.1	58.6	50.2	38.6	25.2	5.5
				Ave.Year	38.4	Ave.Month	10.5	12.5	22.8	36.4	49.9	59.0	64.5	62.6	53.8	43.0	30.2	15.5
				Max.Year	45.6	Max.Month	25.4	26.0	37.2	44.6	58.2	64.8	72.9	71.4	60.8	51.9	41.1	31.8
Woodland,Me.	7	1931-61	140	Min.Year	40.9	Min.Month	8.9	8.2	21.4	36.0	46.8	57.7	64.0	62.5	53.8	42.8	27.3	10.6
				Ave.Year	43.1	Ave.Month	17.5	18.7	28.5	40.8	52.2	61.4	68.0	66.5	57.9	47.2	36.1	22.2
				Max.Year	45.7	Max.Month	30.2	30.1	37.2	43.5	52.0	59.0	64.7	64.3	58.6	53.6	43.3	34.6
Eastport,Me.	8	1873-1961	80	Min.Year	41.0	Min.Month	15.6	13.2	26.0	36.0	45.2	53.4	59.4	59.4	53.6	44.2	31.4	17.6
				Ave.Year	43.0	Ave.Month	22.9	23.5	30.8	40.1	48.7	55.8	61.5	61.9	56.7	48.6	39.0	26.8
				Max.Year	44.2	Max.Month	26.2	23.7	37.3	46.2	58.3	65.8	70.3	69.7	60.4	52.5	41.0	29.3
Berlin,N.H.	30	1917-60	1,110	Min.Year	39.6	Min.Month	8.5	5.7	19.5	33.8	47.2	56.4	62.7	59.8	50.5	42.3	27.0	11.0
				Ave.Year	42.0	Ave.Month	16.1	17.6	26.8	40.5	52.4	61.7	66.5	64.3	56.3	47.6	34.4	20.2
				Max.Year	47.8	Max.Month	26.4	27.5	38.5	47.8	58.8	67.0	73.5	71.4	61.8	54.6	43.8	32.7
Winthrop,Me.	19	1931-61	173	Min.Year	43.7	Min.Month	11.0	16.1	23.3	38.8	49.7	59.7	65.2	64.3	55.2	45.4	35.4	15.1
				Ave.Year	45.2	Ave.Month	19.4	22.1	31.1	43.3	54.8	63.6	69.0	67.5	59.7	49.5	38.3	24.3

(a) Data based on 30-year period 1931-60 except for station 1 where period of record is used.

form of snow during these two months. The duration of an inch or more of snow cover varies from about 80 days along the coast to 120 days or more in northern areas. The water content of the snow cover in early spring is from 3 to 5 inches near the coast. Further inland, snow cover with 6 to 8 inches of water content often occurs, and 10 inches or more is quite common at higher elevations.

Temperature

Sub-region A's average annual temperature varies from about 45° F. near the coast to 38° F. in the northern headwaters. As might be expected from the latitude of the Sub-region, it is the coldest in the NAR. During a normal winter, the temperature averages about 15° F., with temperatures below 0° F. on approximately 30 days each year. The number of days with sub-zero temperatures increases rapidly with distance from the coast, and is more than 50 days in the St. John Basin and in the highest elevations near the northern Maine-New Hampshire border. The largest of the growing season varies from about 160 days along the coast to less than 100 days in extreme northern and northwestern Maine. Temperature data at selected stations is shown in Table C-28.

Humidity

Mean relative humidity generally averages about 75% in January and 70% in July, with a 75% annual average. The wider daily fluctuations are shown by a mean of 88% at Caribou, Me., at 1 a.m. and 58% at 1 p.m. in July. Mean dew point temperatures are about 10° F. in January and 55° F. in July, with an annual average of about 35° F. The annual average dewpoint is 31° F. at Caribou, and 37° F. at Portland, Me.

Wind

The average wind velocity in the Sub-region is from 8 to 10 m.p.h. North-to-northwest winds prevail during the winter, and southwesterly and southerly winds prevail in summer. Local topographic influences result in wind directions parallel to the valleys. Onshore coastal winds blow several miles inland in spring and tend to reduce spring growth.

Coastal storms, or northeasterns, produce very strong winds along the coast, and the occasional storm of tropical origin in summer or fall may result in winds or near-hurricane force (75 m.p.h.). Locally, thunderstorms and a rare tornado will produce high winds. Thunderstorms occur on an average of 20 days a year, mostly in the summer, with the coastal area somewhat below average, and as much as up to 30 days in some places inland. On the average, tornadoes probably occur at least once a year, predominantly in July. Many are undoubtedly not reported, however, because of the large unsettled

TABLE C-33
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION A
(Cubic feet per second)

Sta.			1 Month		6 Months		54 Months	
			Max.	Min.	Max.	Min.	Max.	Min.
118		Hist.	109,574	441	145,181	5,927	614,714	364,141
	Gen.	High	118,624	578	226,271	8,454	768,348	361,338
		Low	72,523	37	140,353	4,840	643,718	283,999
169		Hist.	28,263	42	46,775	1,511	187,716	101,071
	Gen.	High	33,758	87	96,684	1,649	227,948	96,118
		Low	20,756	6	46,911	764	182,809	72,826
151		Hist.	11,564	9	27,593	1,308	126,091	74,775
	Gen.	High	15,840	14	35,290	1,774	151,616	75,661
		Low	10,210	0	28,747	1,023	136,958	61,940
153		Hist.	39,067	141	81,460	5,143	424,087	244,130
	Gen.	High	120,326	222	181,206	6,648	473,594	244,715
		Low	29,574	68	90,965	4,565	422,620	196,726
154		Hist.	16,025	0	38,166	1,292	175,584	104,930
	Gen.	High	44,677	5	71,700	1,659	211,305	102,975
		Low	14,252	0	41,117	834	188,489	79,573
155		Hist.	28,944	0	61,042	2,425	298,380	181,155
	Gen.	High	96,501	96	137,709	3,243	394,387	172,838
		Low	25,766	0	69,875	1,853	316,870	138,720

TABLE C-33 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION A

Sta.		1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
	Hist.	48,310	400	103,834	5,733	520,309	280,950
176	Gen. High	111,842	518	192,470	7,811	610,927	295,602
	Gen. Low	46,813	318	117,743	5,425	517,147	233,396
	Hist.	7,066	67	13,957	791	72,548	37,490
107	Gen. High	10,220	72	22,039	803	82,621	36,685
	Gen. Low	6,409	11	14,644	629	66,242	30,048
	Hist.	3,798	16	10,297	377	43,845	24,058
181	Gen. High	7,798	17	16,375	448	53,743	23,531
	Gen. Low	3,533	7	9,432	247	43,671	19,002
	Hist.	15,796	59	33,368	1,665	178,590	99,071
110	Gen. High	28,172	59	44,918	2,116	205,242	98,002
	Gen. Low	15,188	18	36,735	1,256	170,834	78,590
	Hist.	77,336	114	148,246	9,065	823,351	507,503
162	Gen. High	95,791	435	205,906	14,107	897,802	469,832
	Gen. Low	63,085	43	161,198	7,719	770,807	403,744
	Hist.	9,509	331	28,727	5,118	162,507	93,385
120	Gen. High	16,507	456	35,041	5,010	164,229	100,318
	Gen. Low	9,845	287	28,257	3,886	149,260	86,337

TABLE C-33 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION A

Sta.			1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
		Hist.	23,520	35	53,267	2,822	254,496	152,563
152	Gen.	High	60,001	96	94,297	3,427	290,858	143,363
		Low	19,660	13	57,507	2,127	256,239	116,893
		Hist.	10,931	63	21,815	716	100,618	54,412
117	Gen.	High	10,569	56	30,609	992	117,225	51,729
		Low	9,038	14	19,845	619	93,093	40,446
		Hist.	18,614	33	43,621	1,534	222,452	131,153
158	Gen.	High	22,083	45	65,266	1,982	255,610	121,230
		Low	18,848	0	43,120	748	221,983	87,752
		Hist.	74,795	102	94,250	3,127	339,215	176,858
115	Gen.	High	95,058	204	152,342	3,430	403,075	176,794
		Low	49,055	65	77,510	2,047	314,097	134,711
		Hist.	21,945	58	32,448	1,712	147,836	82,489
114	Gen.	High	27,489	107	54,292	1,855	181,550	81,111
		Low	15,558	6	33,694	1,219	146,710	64,912
		Hist.	19,773	119	27,820	1,231	123,804	73,728
116	Gen.	High	20,059	121	41,540	1,707	152,240	70,444
		Low	14,380	45	28,369	992	126,132	54,243

TABLE C-34

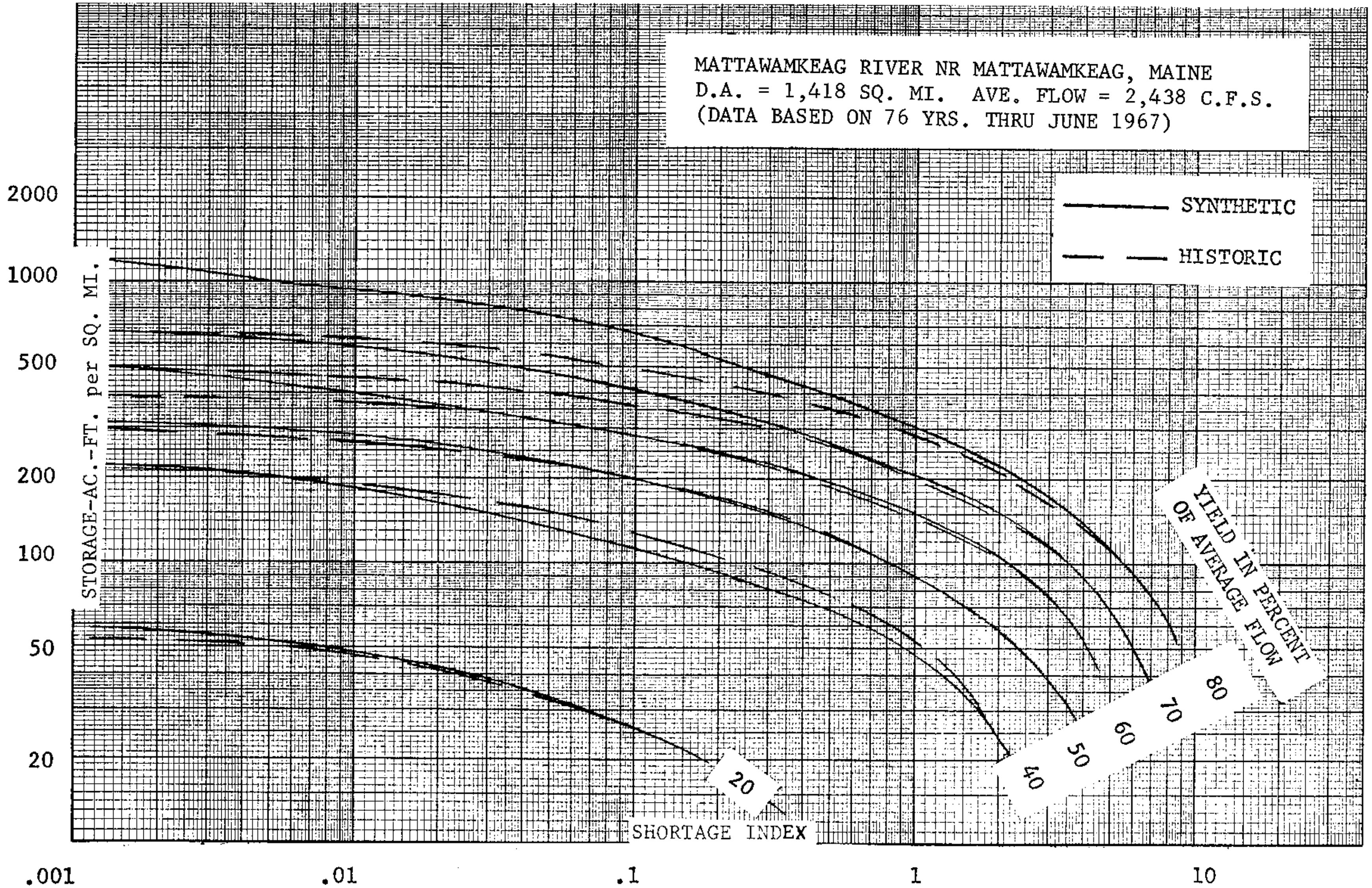
STORAGE REQUIREMENT IN AF/SQ. MI. FOR INDICATED PERCENTAGES OF AVERAGE FLOW

SUBREGION A.

Station	D.A. SQ.MI.	AVERAGE FLOW.CFS.	S.I. = 0.0 HISTORIC 20%	40%	60%	80%	S.I. = 0.01 H 20%	S 20%	H 40%	S 40%	H 60%	S 60%	H 80%	S 80%	S.I. = 0.10 SYNTHETIC 20%	40%	60%	80%
St. John R. - Ninemile Brdg.Me.	1290	2198	50	225	400	750	34	66	170	210	345	440	700	1150	26	150	320	800
St. John R. - Dickey,Me. (Lcl)	1410	2415	72	270	490	810	54	65	210	240	405	450	720	1300	31	175	330	840
St. John R. - Dickey,Me.	2700	4600	50	220	420	750	39	-	180	200	350	410	660	1200	-	150	320	800
Allagash R. - Allagash,Me.	1250	1876	46	190	360	650	32	32	150	155	310	320	600	920	15	100	225	550
Fish R. nr. Fort Kent,Me.	871	1400	70	215	420	880	44	56	195	185	380	375	800	1150	21	130	280	680
St. John R. blw Fish River at Fort Kent Me. (Lcl)	869	1495	80	280	460	1750	68	68	200	230	380	580	1500	1200	46	160	390	900
St. John R. blw Fish River at Fort Kent Me.	5690	9306	45	210	375	700	29	40	160	180	315	360	680	1000	13	125	240	660
Aroostook R. - Washburn,Me.	1652	2688	76	250	460	1050	57	80	215	220	400	470	940	1400	40	160	340	890
Machias R. - Whitneyville, Me.	457	910	33	135	340	830	21	22	105	120	270	300	720	760	-	72	190	470
St. Croix R. - Baileyville, Me.	1320	2270	-	44	150	430	-	-	19	21	100	115	340	390	-	-	28	200
W.Br. Penobscot R. Millnocket,Me.	1910	3068	69	210	370	750	55	55	185	230	350	480	670	1150	28	160	335	770
E.Br. Penobscot R. - Grindstone,Me.	1070	1912	67	215	410	750	45	42	170	190	350	420	640	900	19	110	280	630
Mattawamkeag R. nr. Mattawamkeag,Me.	1418	2438	60	230	410	690	48	48	190	185	365	400	620	920	26	110	280	660
Piscataquis R. nr. Dover-foxcraft,Me.	297	594	77	260	490	900	57	61	220	220	420	500	820	1100	34	150	340	700
Penobscot R. at W. Enfield,Me. (Lcl)	1905	3596	54	230	410	790	28	33	185	120	350	280	680	810	-	65	200	460
Penobscot R. at W. Enfield,Me.	6600	11600	45	175	330	620	23	28	140	140	290	320	540	820	-	85	235	540
Kennebec R. at The Forks, Me.	1589	2566	70	205	365	800	50	58	160	180	300	300	700	1000	31	120	260	680
Kennebec R. at Bingham,Me. (Lcl)	1131	1810	80	225	410	690	60	44	180	190	340	410	620	960	23	115	280	650
Kennebec R. Waterville,Me. + 400 cfs. (Lcl)(a)	1550	3022	73	235	520	1450	52	62	185	190	460	690	1250	1700	26	120	410	1200
Kennebec R. Waterville,Me. + 400 cfs.	4270	7354	40	175	350	760	19	25	140	140	300	400	690	1150	-	78	250	720
Sebasticoole R. nr. Pittsfield,Me.	579	934	40	170	325	810	27	29	130	145	280	380	700	940	-	92	240	640
Androscoggin R. at Errol, N.H.	1045	1900	69	220	430	850	50	60	180	210	370	470	760	1050	34	130	310	740
Androscoggin R. at Rumford, Me. (Lcl)	1022	1760	70	170	350	800	48	50	155	165	310	390	710	1000	25	115	260	600
Androscoggin R. nr. Auburn, Me. (Lcl)	1190	2178	110	285	480	870	80	40	230	140	400	350	760	880	17	85	240	600
Androscoggin R. nr. Auburn, Me. (Total)	3257	5832	50	185	360	720	33	33	150	140	310	360	620	1000	14	95	240	600

(a) 400 cfs added to published streamflows as per USGS instructions.
H = Historic Record
S = Synthetic Record, Avg. of 10 periods @ 100 yrs. ea.
S.I. = Shortage Index

FIGURE C-30. SAMPLE YIELD-STORAGE CURVES - SUB-REGION A



flow for each Sub-area in Sub-region A ,for a shortage index of 0.01. As described in Chapter 3, the seven day minimum flows are considered to have recurrence intervals of about 50 years.

Minimum flow data has been used in studies of existing and practical development resources covered in Appendix E and in connection with NAR Supply Model analyses.

TABLE C-35
EXISTING MINIMUM STREAMFLOW - SUB-REGION A
(Cubic feet per second)

	MONTHLY	7-DAY
Sub-area 1a 1/	1,465	990
Sub-area 1b	422	285
AREA 1	1,887	1,275
AREA 2	5,020	3;970
AREA 3	3,200	2,560
Sub-area 4a	1,310	1,040
Sub-area 4b	860	690
AREA 4	2,170	1,730
Sub-area 5a 2/	874	615
Sub-area 5b	1,390	970
AREA 5	2,264	1,585
SUB-REGION A 3/	14,541	11,120

1/ Includes 733 c.f.s. (monthly) and 492 c.f.s. (7-day) from contributing drainage area in Canada.
2/ Includes 334 c.f.s. (monthly) and 235 c.f.s. (7-day) from contributing drainage area in Canada.
3/ Includes 1,067 c.f.s. (monthly) and 727 c.f.s. (7-day) from contributing drainage area in Canada.

SUB-REGION B

Sub-region B includes the Saco, Merrimack, Connecticut, Thames and Housatonic River Basins, and the southeastern New England coast. Its topography varies from lowlands along the southern coast to the mountain ranges in the northwest. Areas and Sub-areas included in the Sub-region are shown in Figure C-1.

Average annual precipitation is about 44 inches, with a fairly even seasonal and geographic distribution. Annual snowfall varies in relation to latitude and latitude, ranging from 15 inches near the southern coast to more than 180 inches at the summit of Mt. Washington in New Hampshire. The Sub-region is affected by frequent and severe storm types, with high winds and heavy precipitation, which originate in the north Atlantic Ocean as a result of cyclonic polar air masses.

Average annual temperatures range from 50° F. in the southern portion of the Sub-region to about 41° F. in the north. Sub-region B's growing season ranges in length from 100 to 190 days. Surface wind velocities average from 5 to 12 m.p.h., and are primarily from the northwest. Average annual lake evaporation ranges from about 22 inches in northern New Hampshire to 30 inches in southern Connecticut.

The Sub-region's average annual runoff is approximately 23 inches, with a fairly uniform geographic distribution. Most of the annual total occurs in the spring. Flooding, both coastal and fluvial,which are caused mainly by hurricanes, results in peak flows which rank among the highest in the NAR. Prolonged periods of low runoff have occurred several times in recent history, with the recent 1960's drought being felt most severely because of its long duration of from three to as many as five years in some locations. The existing minimum seven-day flow is equivalent to about 0.19 c.s.m.(Shortage Index 0.01).

The overall natural surface quality of the water is considered good. Many suitable aquifers of permeable sand and gravel provide ground water of good quality.

Coastal areas include many bays, estuaries and numerous small pocket beaches, and are generally susceptible to local changes because of winds, currents and coastal storms. This is particularly true where unconsolidated glacial deposits are prevalent.

CLIMATE AND METEOROLOGY

Meteorologic Records

Sub-region B has an even, although relatively sparse, distribution of meteorologic stations. Figure C-31 shows the location of some of these stations. A factor which diminishes the value of meteorologic data is the lack of stations capable of simultaneous recording of several climatological parameters, such as snow, temperature and precipitation. However, many of the meteorologic stations have maintained continuous records for 70 years or more, providing fairly lengthy statistical samples for available analysis.

Precipitation

Based on meteorologic and hydrologic data summarized in this Appendix, there is a fairly uniform distribution of average annual precipitation throughout the Sub-region, as well as relatively even monthly and seasonal distributions. The average annual precipitation, based on the 30-year records of 40 stations, is 44.1 inches, varying from a maximum of about 74 inches at Mt. Washington in New Hampshire to a minimum of about 36 inches at St. Johnsbury, Vt. During the winter season (December, January and February), there is an average of 10.2 inches of precipation and the Sub-region receives nearly equal amounts of rainfall (11.3 inches) in the spring, summer and fall seasons.

Extreme monthly variations have ranged from 25.7 inches in August at Barkhamsted, Conn., to 0.01 inches in June at Nantucket Island, Mass., and traces at Block Island, R.I. Table C-36 summarizes precipitation data for Sub-region B.

The Sub-region receives a substantial amount of snow, generally from late November to late March, with ranges of from 15 to 30 inches at the southern coast to 80 to 100 inches in the northern interior. As expected, snowfall increases with elevation in the interior to a maximum annual average of 185 inches at the summit of Mt. Washington, N.H. (gage elevation 6,262 feet). Table C-37 summarizes mean snowfall data.

Consideration of major storm types contributing to extremes in precipitation and snowfall reveals that the most frequent and serious appear to be the northeasters or cyclonic maritime-polar air masses of north Atlantic Ocean origin. These storms, which affect the northeastern coast of the United States, are characterized by high winds, creating damaging storm surges which affect low-lying coastal areas, and extreme amounts of precipitation.

Hurricanes and tornadoes are less frequent but potentially more

TABLE C-36

PRECIPITATION DATA -SUBREGION B(in inches)

Station	Map Code	Period of Record	Elevation ft.,m.s.l.	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Annual (a)
					Monthly Data (a)												
St. Johnsburg, Vt.	60	1894-1961	699	Max	5.06	4.04	6.24	5.83	6.36	7.13	6.95	6.35	7.57	8.07	5.81	4.38	
				Min	0.92	0.52	1.10	0.49	1.16	0.66	1.21	1.09	1.14	1.03	0.59	1.01	
				Mean	2.57	2.14	2.44	2.82	3.23	3.77	3.47	3.27	3.48	3.06	3.15	2.59	35.99
Mt. Washington, N.H.	32	1933-65	6262	Max	18.23	14.67	15.57	10.03	13.41	10.95	10.70	13.14	14.07	13.49	10.95	13.35	
				Min	1.80	2.64	2.15	2.19	1.78	3.30	2.69	2.77	2.74	0.75	2.31	1.49	
				Mean	5.44	5.21	5.74	5.89	5.84	6.50	6.71	6.65	7.00	6.19	6.61	6.31	74.09
Hanover, N.H.	39	1835-1960	603	Max	6.62	4.45	5.63	6.26	6.82	5.90	9.17	8.92	8.88	5.57	5.76	4.67	
				Min	0.99	1.16	1.26	0.49	1.11	0.43	1.37	0.66	0.78	0.45	1.00	0.61	
				Mean	2.87	2.40	2.77	3.13	3.30	3.24	4.18	3.07	3.38	2.82	3.36	2.72	37.24
Portland, Me.	23	1871-1965	47	Max	12.29	7.35	9.97	9.35	7.74	6.35	5.94	8.30	9.81	6.72	8.00	8.09	
				Min	0.76	1.56	1.07	0.71	0.78	0.70	0.75	0.27	0.30	0.26	0.56	0.98	
				Mean	4.37	3.80	4.34	3.73	3.41	3.18	2.86	2.42	3.52	3.20	4.17	3.85	42.85
Concord, N.H.	37	1856-1965	342	Max	5.87	5.54	9.80	6.36	8.26	10.10	7.57	6.01	10.68	6.79	7.59	7.64	
				Min	0.73	1.13	1.20	0.42	0.60	1.25	0.96	0.95	0.41	0.48	0.50	0.58	
				Mean	3.23	2.48	3.26	3.31	3.17	3.60	3.41	2.96	3.75	2.66	3.72	3.25	38.80
Boston, Mass.	72	1871-1965	15	Max	9.54	5.87	11.00	7.82	13.38	9.13	9.46	17.09	10.94	7.18	7.66	8.19	
				Min	0.92	1.23	1.50	1.59	0.25	0.48	0.52	0.85	0.35	0.34	0.65	0.66	
				Mean	3.94	3.32	4.22	3.77	3.34	3.48	2.88	3.66	3.46	3.14	3.93	3.63	42.77
Pittsfield, Mass.	84	1938-65	1170	Max	4.77	5.04	6.83	6.66	7.23	10.32	8.34	8.20	7.95	7.04	6.36	9.34	
				Min	1.22	1.02	1.10	2.65	1.51	1.76	2.03	0.60	0.95	0.78	1.35	0.90	
				Mean	2.97	2.51	3.22	3.87	3.87	4.28	4.89	3.90	4.50	3.25	3.91	3.25	44.42
Stockbridge, Mass.	85	1930-65	870	Max	5.35	4.70	7.40	6.01	6.75	8.59	11.73	12.18	11.81	7.94	6.44	9.73	
				Min	0.96	0.82	1.05	0.82	1.06	1.64	1.16	0.86	1.90	0.93	1.04	0.75	
				Mean	3.26	2.63	3.26	3.74	3.61	3.99	4.46	3.81	4.10	2.93	3.82	3.22	42.83
Hubbardston, Mass.	80	43	1030	Max	6.17	4.83	8.89	7.62	6.96	11.82	8.00	9.83	18.28	8.05	7.44	6.83	
				Min	0.61	1.18	1.32	1.01	1.17	0.46	1.07	0.79	0.94	0.13	0.95	0.50	
				Mean	2.92	2.44	3.38	3.60	3.45	4.00	4.10	3.45	4.25	3.28	4.04	2.96	41.87
Worcester, Mass.	78	1892-1965	986	Max	8.11	5.44	11.13	6.61	7.38	7.39	11.41	18.68	10.82	10.98	8.87	7.77	
				Min	0.59	1.42	1.52	0.85	0.86	0.97	0.63	0.90	0.58	0.47	0.98	0.68	
				Mean	3.71	2.92	4.11	3.93	3.79	3.84	3.63	4.24	3.92	3.47	4.26	3.59	45.41
Westfield, Mass.	83	1931-60	220	Mean	3.60	3.01	4.05	4.08	3.78	4.16	3.88	4.34	4.30	3.50	4.20	3.59	46.49
Hartford, Conn.	90	1905-65	169	Max	7.23	5.28	9.21	6.93	7.04	8.08	11.24	21.87	14.59	11.61	7.36	6.88	
				Min	0.91	1.65	1.84	0.65	0.73	0.87	1.35	0.93	0.63	0.65	0.87	0.78	
				Mean	3.58	2.94	3.80	3.73	3.41	3.70	3.61	4.01	3.65	3.18	3.84	3.47	42.92
Nantucket, Mass.	76	1887-1965	43	Max	8.24	8.07	8.88	8.41	8.24	6.55	7.45	12.92	9.55	8.31	8.76	7.04	
				Min	1.21	1.30	1.84	0.90	0.86	0.01	0.15	0.28	0.42	0.37	1.06	1.10	
				Mean	4.22	3.76	4.54	3.76	2.88	2.92	2.71	3.68	3.51	3.70	4.05	3.93	43.66
Block Island, R.I.	102	1881-1965	110	Max	6.74	6.32	8.52	5.86	8.37	6.53	6.71	9.73	11.36	8.74	9.73	6.37	
				Min	0.73	1.27	1.61	1.81	0.72	T	0.39	0.69	0.08	0.22	0.86	0.83	
				Mean	3.84	3.29	4.07	3.61	3.01	2.56	2.69	3.86	3.20	3.02	3.71	3.59	40.45
New Haven, Conn.	93	1872-1965	6	Max	8.35	6.46	10.78	6.71	7.77	13.96	7.45	10.95	14.52	10.06	8.14	8.34	
				Min	0.63	1.49	1.67	1.32	0.89	0.12	0.52	0.72	0.32	0.63	0.85	0.96	
				Mean	3.96	3.19	4.62	3.89	3.71	3.53	3.43	4.24	3.93	3.45	4.05	4.02	46.02

(a) Data based on 30-year period 1931-60 except where record begins after 1931.

TABLE C-37

SNOW DATA - SUBREGION B

Station	Map Code	Years of Record	Elevation ft.,m.s.l.	Mean Snowfall in inches (a) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
First Conn.Lake,N.H.	33	42	1660	35.9	35.4	28.3	13.3	2.1	T	T	0	T	3.9	18.7	34.7	172.3
St.Johnsburg,Vt.	60	30(1931-60)	699	21.6	18.9	13.8	3.4	0.1	0	0	0	T	0.7	6.4	14.7	79.6
Mt.Washington,N.H.	32	33	6262	29.6	32.8	32.1	22.9	8.7	1.4	T	0.2	1.4	11.0	25.1	34.0	199.2
Pinkham Notch,N.H.	41	28	2000	35.4	33.7	35.8	20.0	2.1	T	0	T	T	2.3	15.3	28.2	172.8
Portland,Me.	23	25	47	18.9	19.0	14.0	2.6	0.3	0	0	0	T	0.2	2.9	13.1	71.0
Woodstock,N.H.	42	22(1942-63)	720	25.7	24.3	17.6	3.7	0.3	0	0	0	T	0.3	6.3	19.7	97.9
Chelsea,Vt.	54	63	830	21.0	19.8	16.6	6.5	0.6	0	0	0	0	1.0	8.4	15.1	89.0
Lakeport,N.H.	43	28(1938-65)	560	21.1	18.6	17.3	4.1	0.4	0	0	0	0	0.1	4.7	14.6	80.9
Hanover,N.H.	39	30(1931-60)	603	19.5	18.4	13.6	4.1	0.4	0	0	0	0	0.3	5.3	12.9	74.5
Franklin,N.H.	36	30(1931-60)	390	20.2	15.7	12.0	3.3	0.1	0	0	0	T	0.1	3.5	11.1	66.0
Concord,N.H.	37	24	342	17.8	13.9	11.3	1.7	0.2	0	0	0	0	T	3.1	12.5	60.5
Durham,N.H.	38	30(1931-60)	70	17.1	13.6	10.9	2.2	0	0	0	0	0	T	2.7	9.1	55.6
Keene,N.H.	40	30(1931-60)	490	17.6	14.4	11.9	3.0	T	0	0	0	0	0.1	5.1	10.2	60.3
Haverhill,Mass.	70	31(1930-60)	60	15.6	14.2	10.9	1.9	T	0	0	0	T	T	2.3	8.7	53.6
Cape Ann Rockport Gloucester,Mass.	71	17	80	13.7	13.7	11.2	0.8	0	0	0	0	0	T	0.4	7.3	47.1
Boston,Mass.	72	30(1931-60)	15	12.7	11.2	7.9	0.7	T	0	0	0	0	T	1.3	7.1	40.9
Blue Hill Milton, Mass.	73	80	629	15.6	16.0	11.5	3.2	0.1	0	0	0	0	0.2	2.7	10.4	59.7
Worcester,Mass.	78	10	986	16.6	19.3	20.4	4.9	T	0	0	0	0	1.2	1.4	12.9	76.7
Pittsfield,Mass.	84	22	1170	18.6	20.3	13.0	5.1	0.2	0	0	0	0	0.2	4.8	13.5	75.7
Stockbridge,Mass.	85	31(1935-65)	870	18.3	16.3	12.4	3.8	0.2	0	0	0	0	T	4.8	10.8	66.6
Plymouth,Mass.	74	30(1931-60)	25	9.4	9.3	7.0	0.3	0	0	0	0	0	T	0.6	5.3	31.9
East Wareham,Mass.	75	30(1931-60)	25	7.5	7.2	6.6	0.1	0	0	0	0	0	T	0.5	5.1	27.0
Hyannis,Mass.	86	20	35	6.1	8.3	5.0	0.1	0	0	0	0	0	T	0.5	3.5	23.5
Hartford WBAP,Conn.	90	16	169	11.4	10.0	9.0	1.5	0	T	0	T	0	T	1.1	7.2	40.2
Providence,R.I.	100	16	51	9.5	8.4	8.2	0.8	T	T	T	0	0	T	0.9	7.6	35.4
Fall River,Mass.	77	31(1930-60)	190	8.9	8.5	7.3	0.5	T	0	0	0	0	T	1.1	5.5	31.8
Nantucket,Mass.	76	19	43	9.7	10.2	7.3	1.0	0	0	0	0	0	T	0.2	7.2	35.6
Kingston,R.I.	101	60	100	8.4	9.2	6.5	1.0	T	0	0	0	0	T	1.3	6.2	32.6
Block Island,R.I.	102	80	110	4.7	6.2	4.3	0.7	0	0	0	0	T	0	3.5	3.7	23.1
New Haven,Conn.	93	22	6	9.7	10.0	6.7	0.8	T	0	0	0	0	0.1	1.0	8.5	36.8
Bridgeport,Conn.	94	17	7	7.7	7.3	5.2	0.6	T	0	0	0	0	T	0.5	4.9	26.2

(a) Data based on number of years indicated in third column.

destructive. Fortunately, tornadoes are a more locally-created phenomenon, and affect relatively small areas . Hurricanes, which are of tropical origin, may affect the entire Sub-region. Most hurricanes either lose their destructive force or head out to sea by the time they reach the Sub-region. However, a few, notably the more recent ones of 1938, 1944, 1954 and 1955, have crossed the Sub-region at nearly full force with high winds and heavy precipitation, creating enormous property damage and causing great loss of life.

Thunderstorms are of a relatively local nature. When accompanied by hail and high winds, a summer thunderstorm can cause considerable damage to crops and property.

While the occasional storms can result in high precipitation, minimal amounts of rainfall, or drought-like conditions in the northeastern United States, result from processes which are not yet fully understood. Unlike the western part of the country, where lack of rainfall is the result of the high Rocky Mountain Range interfering with the normal west-to-east motion of air masses, and thus a permanent feature of the western climate, droughts in the east seem to occur irregularly with some statistically-correlated evidence pointing to a combination of lunar and solar influences.

Another line of evidence in connection with droughts indicates that the jet stream, which normally dips down to the Gulf Coast and then up again along the east coast bringing warm moist air to the north, sometimes moves in a straight west to east pattern. The cause of this failure of the jet stream to dip south is not known at the present time.

Temperature

The average annual temperature varies from 50° F. in the southern coastal region to 41° F. in the northern part of the Sub-region. The average annual temperatures are influenced not only by proximity to the ocean, and its underating influence, but also by differences in elevation, particularly in the interior of the Sub-region.

The Sub-regional temperature range is greatest during the winter months, varying approximately 20 degrees, from an average of 10° F. in the north to 32° F. on the coast. The extremes of temperature recorded in the Sub-region range from -50° F. to 106° F., with approximately 10 days per year of temperatures above 90° F. Days with sub-zero temperatures are more common, averaging 25 to 50 per year inland. The length of the growing season increases, north to south, from 100 days to 190 days. Table C-38 summarizes mean temperature data at selected stations.

TABLE C-38

TEMPERATURE DATA -SUBREGION B (in degrees Fahrenheit)

Station	Map Code	Period of Record	Elevation ft.,m.s.l.	Mean Annual Temperature (a)			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
							Mean Monthly Temperature (a)											
St.Johnsbury, Vt.	60	1894-1961	699	Max.Year	46.9	Max.Month	28.4	27.0	40.1	48.4	60.9	69.4	72.6	71.7	63.8	54.0	42.9	29.9
				Min.Year	42.1	Min.Month	10.0	6.0	23.1	36.1	49.7	59.3	65.1	63.0	54.2	44.6	28.2	9.4
				Ave.Year	44.3	Ave.Month	17.8	19.6	29.4	42.9	55.6	65.0	69.3	67.2	59.2	48.3	36.1	21.7
Hanover,N.H.	39	1835-1960	603	Max.Year	47.6	Max.Month	30.0	27.5	40.8	49.4	59.8	69.3	73.0	72.0	63.4	54.3	42.0	31.1
				Min.Year	42.3	Min.Month	12.1	8.0	24.9	37.0	50.2	58.9	66.0	63.4	54.3	44.2	29.6	14.5
				Ave.Year	44.8	Ave.Month	18.9	20.9	30.6	43.4	55.3	64.5	69.2	67.2	59.4	48.3	36.5	22.9
Portland,Me.	23	1871-1965	47	Max.Year	48.6	Max.Month	32.6	30.4	39.5	47.0	56.2	65.0	71.7	72.4	63.2	55.3	44.6	33.1
				Min.Year	43.7	Min.Month	13.9	14.0	25.6	38.4	48.2	58.1	65.1	63.3	54.5	45.8	35.2	18.0
				Ave.Year	45.0	Ave.Month	21.8	22.8	31.4	42.5	53.0	62.1	68.1	66.8	58.7	48.6	38.1	25.8
Concord,N.H.	37	1856-1965	342	Max.Year	48.3	Max.Month	31.8	29.7	41.1	51.4	60.2	68.4	74.1	72.8	63.2	55.2	42.6	32.9
				Min.Year	44.2	Min.Month	13.5	12.0	25.6	38.4	50.8	60.0	66.2	63.6	54.9	46.6	33.1	17.8
				Ave.Year	45.6	Ave.Month	21.2	22.7	31.7	43.8	55.5	64.5	69.6	67.4	59.3	48.7	37.6	25.0
Keene,N.H.	40	1892-1960	490	Max.Year	49.5	Max.Month	32.0	32.4	43.6	51.2	61.7	70.1	74.2	72.3	64.7	55.4	44.1	32.9
				Min.Year	43.6	Min.Month	14.2	10.4	26.9	39.6	50.8	61.1	64.7	62.9	56.3	45.0	32.2	19.0
				Ave.Year	46.6	Ave.Month	22.8	24.2	32.9	45.1	56.4	65.1	69.8	67.8	60.4	49.8	38.5	26.1
Worcester, Mass.	78	1892-1965	986	Max.Year	49.9	Max.Month	34.1	32.4	44.9	51.3	62.5	69.6	74.3	72.7	64.7	57.0	44.7	35.4
				Min.Year	45.2	Min.Month	16.8	14.4	26.1	40.5	52.1	59.9	67.6	64.4	57.0	46.9	35.1	20.9
				Ave.Year	46.8	Ave.Month	24.0	24.9	32.8	44.6	55.2	64.6	69.8	68.3	60.8	50.5	39.2	27.2
Boston,Mass.	72	1871-1965	15	Max.Year	53.6	Max.Month	38.8	36.4	47.2	52.5	63.2	71.6	77.5	74.7	68.1	61.6	49.6	40.2
				Min.Year	48.5	Min.Month	23.0	17.5	32.7	43.4	55.0	63.6	70.8	67.3	61.1	49.6	38.3	26.4
				Ave.Year	51.4	Ave.Month	29.9	30.3	37.7	47.9	58.8	87.8	73.7	71.7	65.3	55.0	44.9	33.3
Plymouth, Mass.	74	1886-1962	25	Max.Year	53.7	Max.Month	41.1	37.0	46.4	52.5	61.5	71.3	76.5	75.1	67.7	60.0	49.7	41.1
				Min.Year	47.4	Min.Month	22.2	19.5	32.4	40.0	54.2	63.1	69.1	66.4	60.9	49.1	38.4	26.8
				Ave.Year	51.0	Ave.Month	30.8	31.2	37.8	47.3	57.6	66.5	72.2	70.7	64.1	54.8	45.0	33.8
E.Wareham, Mass.	75	1912-62		Max.Year	51.5	Max.Month	37.2	34.2	43.0	50.8	59.4	69.1	75.6	73.7	66.4	56.8	47.4	38.3
				Min.Year	47.0	Min.Month	20.9	17.0	30.1	41.4	51.2	61.2	67.8	65.8	59.8	48.0	36.8	23.7
				Ave.Year	49.3	Ave.Month	29.0	29.1	36.1	45.7	55.9	64.7	71.0	69.8	62.8	52.9	43.2	31.9
Fall River, Mass.	77	1887-1960	190	Max.Year	53.3	Max.Month	38.4	36.8	45.7	52.3	62.2	71.2	77.1	74.0	68.0	60.0	49.0	39.6
				Min.Year	47.6	Min.Month	22.2	17.8	31.8	42.9	53.4	62.9	69.2	66.9	61.4	48.6	38.3	25.8
				Ave.Year	50.7	Ave.Month	29.7	30.2	37.2	47.3	57.8	66.6	72.7	71.7	64.3	54.5	43.8	32.9
Providence, R.I.	100	1905-65	51	Max.Year	54.4	Max.Month	38.6	36.2	48.4	54.5	64.2	72.2	78.2	75.6	68.4	61.4	49.8	38.4
				Min.Year	48.8	Min.Month	22.7	17.4	31.5	43.9	53.4	62.5	70.3	67.8	60.1	50.4	38.8	25.3
				Ave.Year	50.1	Ave.Month	29.2	29.7	37.0	47.2	57.5	66.2	72.1	70.5	63.2	53.2	43.0	32.0
Nantucket, Mass.	76	1887-1965	43	Max.Year	51.6	Max.Month	40.3	36.2	43.2	49.3	57.2	65.0	71.6	71.8	66.8	57.7	50.0	41.3
				Min.Year	48.0	Min.Month	25.8	22.6	31.8	41.8	48.7	58.0	65.7	64.9	59.9	51.0	41.4	28.6
				Ave.Year	49.5	Ave.Month	33.0	31.4	36.1	44.3	52.6	61.3	68.0	68.1	62.9	54.3	45.9	36.1
Block Island, R.I.	102	1881-1965	110	Max.Year	52.8	Max.Month	40.4	36.9	42.9	48.8	57.4	66.4	73.8	72.8	66.4	60.0	50.6	41.8
				Min.Year	48.3	Min.Month	25.2	20.3	32.4	41.4	49.8	59.8	66.8	66.4	61.8	51.0	41.6	28.8
				Ave.Year	50.1	Ave.Month	32.1	30.9	36.7	44.6	53.9	62.9	69.6	69.6	64.0	55.2	45.2	35.9
New Haven, Conn.	93	1872-1965	6	Max.Year	53.1	Max.Month	39.6	36.7	44.0	53.5	61.4	72.8	75.4	75.2	69.2	58.1	48.4	37.6
				Min.Year	49.0	Min.Month	22.8	17.4	31.7	43.4	53.6	62.3	69.4	67.5	61.2	50.8	39.4	26.7
				Ave.Year	50.1	Ave.Month	29.6	29.6	36.9	46.9	57.2	66.2	71.9	70.6	63.9	54.0	43.4	32.4
Bridgeport, Conn.	94	1893-1965	7	Max.Year	53.9	Max.Month	38.8	37.1	46.4	53.4	63.2	72.6	77.4	76.1	69.4	67.6	38.4	26.4
				Min.Year	48.4	Min.Month	21.8	15.6	32.1	43.6	54.9	64.0	71.1	68.0	61.6	49.4	48.8	38.8
				Ave.Year	51.5	Ave.Month	30.2	30.5	37.5	48.0	58.7	68.0	73.7	72.3	65.5	55.4	44.5	33.2

(a) Data based on 30-year period 1931-60 except where record begins after 1931.

Humidity

Mean relative humidity generally averages about 75% in January and 70% in July. The mean annual is about 70%. The mean annual relative humidity at Boston, Mass., and Hartford, Conn., at 1 p.m. is 56%, while at 7 a.m. it is 71% and 76%, respectively, at these locations. Mean dew point temperatures range from 10° F. to 20° F. in January, from 50° F. to 65° F. in July, and are between 30° F. and 40° F. annually. The annual average dew point is 36° F. at Concord, N.H., and 43° F. at New Haven, Conn.

Wind

The Sub-region lies in the belt of prevailing westerlies, with slight seasonal drift in wind direction from the NW quadrant in the winter to winds from the SW quadrant in summer. Topography influences prevailing wind directions locally. For example, the winds in the Connecticut Valley follow the north-south orientation of the valley, blowing from due north in the winter and from due south in the summer. The average wind speed for the Sub-region ranges between 5 and 12 m.p.h.

Evaporation

The average annual surface water evaporation decreases south to north within the Sub-region, from nearly 30 inches in southern Connecticut to 22 inches in northern New Hampshire. The rate of evaporation increases with warm weather, so that 80 % of this evaporation occurs in the northern portion of the Sub-region from May to October, decreasing to 74% in the south.

HYDROLOGY

Existing Resource

Hydrologic Records. Currently, surface water records at approximately 270 stations are compiled and published by the U.S. Geological Survey, in cooperation with the several States. Additional data on river stages are available from the National Weather Service's annual publication, "Daily River Stages," and from miscellaneous reports of the power companies in the Sub-region. Selected streamflow gaging stations referred to in this Appendix are located on Figure C-31.

Average Flow. The average flow amounts to about 50,100 c.f.s. for the total drainage area, including 114 square miles of Canadian drainage area, in the Connecticut River Basin. This is equivalent to 22.9 inches of runoff, about 52% of the average annual precipitation. Runoff averages about 1.7 c.s.m. for the

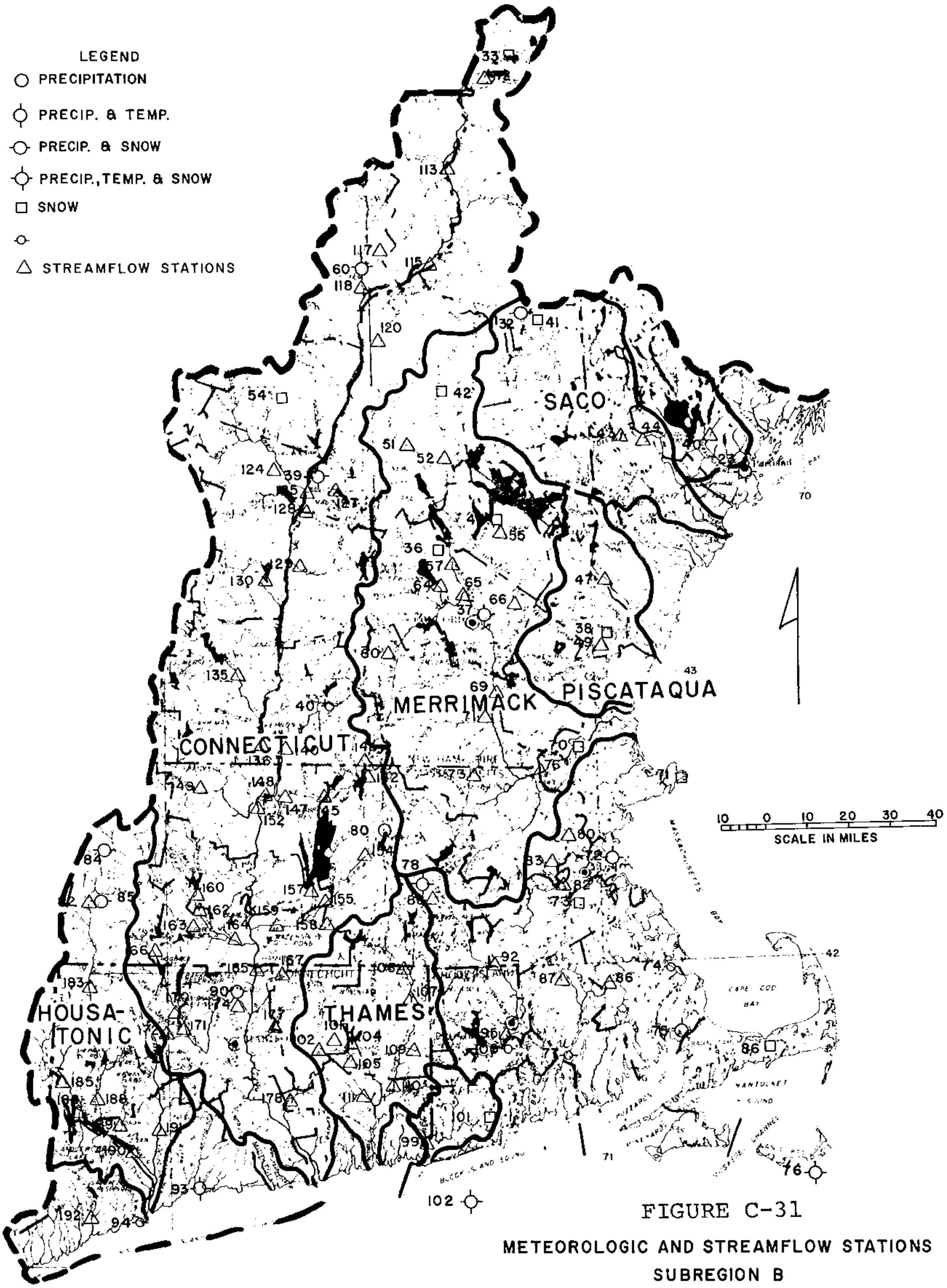


FIGURE C-31

METEOROLOGIC AND STREAMFLOW STATIONS

SUBREGION B

Sub-region, and is highest in the Saco River Basin at 2.1 c.s.m. and lowest, 1.4 c.s.m., in the Piscataqua Basin and along the New Hampshire Coast. Table C-39 lists estimated average runoff for each Sub-area.

TABLE C-39
AVERAGE ANNUAL RUNOFF - SUB-REGION B
(Drainage area in square miles, average runoff in c.f.s.)

	DRAINAGE AREA	AVERAGE RUNOFF
Sub-area 6a	998	1,495
Sub-area 6b	1,697	3,495
Sub-area 6c	1,513	2,150
AREA 6	4,208	7,140
Sub-area 7a	3,092	5,100
Sub-area 7b	1,958	3,230
AREA 7	5,050	8,330
Sub-area 8a 1/	1,514	2,895
Sub-area 8b	4,752	7,490
Sub-area 8c	3,395	5,990
Sub-area 8d	1,589	2,545
AREA 8 1/	11,250	18,920
Sub-area 9a	2,335	3,980
Sub-area 9b	2,241	4,190
AREA 9	4,576	8,170
Sub-area 10a	1,710	2,890
Sub-area 10b	2,845	4,640
AREA 10	4,555	7,530
SUB-REGION B 1/	29,639	50,090

1/ Includes 114 square miles of contributing drainage area in Canada and 218 c.f.s. of average runoff from that area.

Streamflow Variation. Maximum monthly flows have occurred almost exclusively in March and April and generally range from 5 to about 8 times the average flow, and even higher at locations where there is little or no regulation. Minimum months usually occur in August, September and October and are generally between 5% and 10% of average, though smaller values occur where no regulation exists.

Table C-40 lists average, maximum and minimum monthly flow for selected streamflow stations.

Existing Regulation. Sub-region B contains about 4.5 million acre-feet of storage, or 28% of the total in the Region. Storage in Areas 6 and 7 and the northern part of Area 8 is utilized for municipal supply or flood control and recreation. The southern portion of Area 8 contains a number of flood control reservoirs with joint recreational use. Area 9 storage is used mostly for municipal supply, while Area 10 contains mostly flood control and recreation storage with some power usage. Nearly 80% of the Sub-region's storage is located in Areas 7 and 8. Area 8 contains the NAR's largest existing storage project, Quabbin Reservoir, with more than 1.2 million acre-feet of storage operated principally for municipal supply and power. Table C-5 (p.23) shows Sub-region B's major existing storage by Area.

Existing storage has a significant effect on low flow throughout much of the Sub-region. Recorded average low flows in the Saco and Merrimack Rivers have been two to three times higher than would have occurred under natural conditions, and the monthly flows along the Connecticut River main stem are nearly twice the natural flow. On the other hand, hydroelectric power plants are responsible for drastic reductions in flow during non-operating periods such as weekends.

Major interbasin diversion facilities exist in Sub-region B in connection with the Metropolitan District Commission System. The principal elements are the aqueduct for transfer of water between Quabbin Reservoir in Area 8 and Wachusett Reservoir in Area 7 and the system of aqueducts and tunnels carrying water from Wachusett Reservoir into Area 9. The yield of this system is covered further in the Water Availability Analyses section of this Sub-regional Summary.

Quality and Suitability. Sub-region B's natural surface waters are generally suitable for most uses, although control of color, turbidity and iron content may be required in a few places. The waters are generally soft and dissolved solids concentrations are relatively low. Sediment loads are somewhat greater than in Sub-region A, but still relatively low. Average annual sedimentation rates vary from 14 tons per square mile in Area 6 to 57 tons per square mile in Area 9 (See Appendix Q, Erosion and Sedimentation).

Industrial and non-industrial waste sources contributed about 10.6 million population equivalents (PE) of biodegradables, as measured by biochemical oxygen demand (BOD), into the waters of the Sub-region in 1960. Non-industrial sources contributed about 40% of the load, industrial sources the remainder (See Appendix L, Water Quality and Pollution).

TABLE C-40

STREAMFLOW DATA (a) - SUBREGION B

Location	Map Code	D.A., sq.mi.	Years of Record	Average(b) Flow-c.f.s.	Mean Monthly Flow-c.f.s.				Structures Affecting Natural Streamflow
					Maximum(c)	Date	Minimum(c)	Date	
Presumpscot R. at Outlet of Sebago L., Me.	40	436	78	659	4,205	4/02	176	7/15	Long Pond & Sebago Lake
Ossipee R. at Cornish, Me.	43	453	49	863	5,552	3/36	146	10/47	Several power plants, lakes & ponds
Saco River at Cornish, Me.	44	1,298	49	2,659	16,220	3/36	406	10/47	Several power plants, lakes & ponds
Salmon Falls R. nr. So. Lebanon, Me.	47	147	36	237	1,763	3/36	26.4	9/41	Several power plants, lakes & ponds
Lamprey R. nr. Newmarket, N. H.	49	183	31	274	1,866	3/36	3.44	9/57	Pawtuckaway & Mendums Ponds
Baker R. nr. Rumney, N.H.	51	143	37	250	1,464	4/34	18.2	10/49	
Pemigewassett R. at Plymouth, N.H.	52	622	62	1,333	9,266	3/36	107	9/23	Power plants
L. Winnepesaukee Outlet at L'Keport, N.H.	55	363	32	523 *	1,672	2/58	33.2	3/42	Several Lakes
Merrimack R. at Franklin Junct., N.H.	57	1,507	60	2,735	11,360	4/51	555	10/47	Several power plants, reservoirs & lakes
N. Br. Contoocook R. nr. Antrim, N.H.	60	54.8	41	99.1	735	3/36	0.73	9/48	Highland Lake & several ponds
Blackwater R. nr. Webster, N.H.	64	129	40	208	1,330	4/33	16.2	8/50	Blackwater Reservoir
Contoocook R. at Penacook, N.H.	65	766	37	1,231	9,197	3/36	136.	10/41	Several lakes & reservoir
Suncook R. at N. Chichester, N.H.	66	157	44	237	2,155	3/36	9.35	10/48	Mills & reservoir
Merrimack R. nr. Goffs Falls blw Manchester, N.H.	69	3,092	29	5,137	25,520	4/60	745	9/57	Several reservoirs & lakes
Souhegan R. at Merrimack, N.H.	71	171	56	281	2,278	3/36	16.2	9/57	
Nashua R. at East Pepperell, Mass.	73	433	30	526 *	3,930	3/36	84.2	9/41	W.S. diversion from basin
Merrimack R. blw Concord R. at Lowell, Mass.	76	4,635(d)	42	7,077 *	45,780	3/36	895	9/57	Reservoirs, W.S. diversion
Conn R. at 1st Conn lk. nr. Pittsburg, N.H.	112	83.0	48	194 *	744	2/28	6.11	4/40	First and Second Conn. lakes
Conn. R. at No. Stratford, N.H.	113	799	35	1,540 *	7,348	4/34	271	3/40	Several reservoirs
Conn. R. nr. Dalton, N.H.	115	1,514	38	2,840 *	15,380	4/34	406	8/42	Several reservoirs
Ammonoosuc R. nr. Bath, N. H.	120	395	30	647	4,283	3/36	78.0	9/48	
Moose R. at St. Johnsbury, Vt.	117	128	37	217	1,363	4/34	21.4	9/55	
Passumpsic R. at Passumpsic, Vt.	118	436	37	713	4,013	3/36	122	8/34	Power plants
White R. at West Hartford, Vt.	124	690	50	1,158	7,170	3/36	126	9/21	
Conn. R. at White R. Jct., Vt.	125	4,092	54	7,051	35,510	3/36	1,010	10/47	Several reservoirs
Mascoma R. at Mascoma, N.H.	127	153	42	210 *	1,222	3/36	46.1	1/48	Several lakes
Ottauquechee R. at N. Hartland, Vt.	128	221	35	383 *	2,570	3/36	36.3	9/36	North Hartland Reservoir
Sugar R. at W. Claremont, N. H.	129	269	37	388 *	2,672	4/60	56.2	9/36	Sunapee Lake
Black R. at N. Springfield, Vt.	130	158	36	274 *	1,799	3/36	23.3	8/49	North Springfield Reservoir
Ashuelot R. nr. Gilsum, N. H.	137	71.1	43	122	803	3/36	6.83	9/57	Reservoir
S. Br. Ash. R. at Webb nr. Marlborough, N.H.	139	36.0	45	58	366	3/36	2.61	9/53	Several reservoirs
West R. at Newfane, Vt.	135	308	41	601 *	3,887	4/60	21.7	9/48	Ball Mtn. & Townshend Res.
Conn. R. at Vernon, Vt.	136	6,266	21	10,170 *	56,340	3/36	1,679	10/48	Several reservoirs
Ashuelot R. at Hinsdale, N. H.	140	420	55	646 *	4,392	3/36	58.5	9/57	Surry Mtn. & Otter Brk. Res.
Tarbell Brook nr. Winchendon, Mass.	141	18.2	49	29.0	190	3/36	0.88	9/53	Several reservoirs
Millers R. nr. Winchendon, Mass.	142	83.0	49	140	931	3/36	11.6	10/47	Several reservoirs
East Br. Tully R. nr Athol, Mass.	145	50.4	50	80.7 *	525	3/36	0.97	8/56	Tully Reservoir
Millers R. at Erving, Mass.	147	375	51	614 *	3,989	3/36	56.0	8/57	Several reservoirs
Conn. R. at Turners Falls, Mass.	148	7,163	50	11,670 *	64,400	3/36	1,821	10/49	Several reservoirs
Deerfield R. at Charlemont, Mass.	149	362	52	877 *	4,120	4/14	90.8	10/14	Somerset & Harriman Res.
Conn. R. at Montague City, Mass.	152	7,865	61	13,520 *	71,920	3/36	1,830	10/08	Several reservoirs
Ware River at Coldbrook, Mass.	154	96.8	37	163	1,066	3/36	10.4	9/57	Barre Falls Reservoir
Ware R. at Gibbs Crossing, Mass.	155	199	53	317 *	1,838	3/36	30.0	10/14	Barre Falls Res., W.S. diversion
Swift R. at West Ware, Mass.	157	188	53	299 *	1,654	3/36	28.6	6/45	Quabbin Res., diversions

TABLE C-40 CONT.

STREAMFLOW DATA (a) - SUBREGION B

Location	Map Code	D.A., sq.mi.	Years of Record	Average(b) Flow-c.f.s.	Mean Monthly Flow-c.f.s. Maximum(c)	Date	Minimum(c)	Date	Structures Affecting Natural Streamflow
Quaboag R. at W. Brimfield, Mass.	158	151	53	240	1,399	3/36	11.9	10/57	
Chicopee R. at Ind. Orchard, Mass.	159	688	37	1,075 *	5,993	3/36	144	10/47	Several reservoirs, diversions
Westfield R. at Knightville, Mass.	160	162	56	317 *	2,050	3/36	15.7	8/13	Knightville Reservoir
Mid. Br. Westfield R. at Goss Hts., Mass.	162	52.6	55	102	653	3/36	1.51	9/14	Littleville Reservoir
W. Br. Westfield R. at Huntington, Mass.	163	93.7	30	181	1,098	3/36	8.46	8/57	
Westfield R. nr. Westfield, Mass.	164	497	51	929 *	5,064	3/36	91.2	8/57	Several reservoir & diversion
Conn. R. at Thompsonville, Conn.	165	9,661	37	16,070 *	89,200	3/36	3,073	10/48	Several reservoir & diversion
Scantic R. at Broad Brook, Conn.	167	98.4	37	141	597	3/36	20.0	9/57	
W. Br. Farmington R. nr. New Boston, Mass.	166	92	52	178 *	1,002	8/55	5.68	8/57	Otis Reservoir
Nepaug R. nr. Nepaug, Conn.	170	22.7	45	38.7	206	3/36	0.80	1/53	
Clear Brk. nr. Collinsville, Conn.	171	0.58	48	1.62	4.42	10/55	0.52	9/41	
Burlington Brk. nr. Burlington, Conn.	172	4.12	34	7.91	37.6	10/55	0.86	9/41	
Farmington R. at Rainbow, Conn.	174	591	37	1,045 *	6,142	8/55	113	8/57	Several reservoirs & diversions
Hockanum R. nr. E. Hartford, Conn.	177	74.5	39	113 *	406	3/20	25.8	10/30	Shenipsit Lake
Salmon R. at E. Hampton, Conn.	178	105	37	175	797	3/36	6.16	9/53	
Ipswich R. nr. Ipswich, Mass.	79	124	35	200 *	1,045	3/36	2.03	9/57	Several reservoirs & diversions
Mother Brook at Dedham, Mass.	82	-	34	78.8	490	3/36	0	-	
Charles R. at Waltham, Mass.	83	227	34	374 *	1,329	3/36	14.6	8/49	Several reservoirs & diversions
Taunton R. at State Farm, Mass.	86	260	36	480 *	1,600	4/33	28.0	8/34	Several reservoirs & diversions
Wading R. nr. Norton, Mass.	87	42.4	40	71.8 *	354	3/36	2.88	9/57	Several ponds, diversion
Kettle Brook at Worcester, Mass.	88	31.3	42	52.9 *	222	4/56	3.89	10/49	Several reservoirs, diversions
Blackstone R. at Woonsocket, R.I.	92	416	36	719 *	2,646	4/56	113	9/57	Several reservoirs
Pawtuxet R. at Cranston, R. I.	95	200	25	398 *	1,230	4/53	70.5	10/57	Several reservoir, diversion
Pawcatuck R. at Westerly, R. I.	99	295	25	560 *	1,766	3/53	82.2	9/48	Diversion
Quinebaug R. at Quinebaug, Conn.	106	157	34	267 *	1,669	3/36	12.2	9/57	Several reservoirs
Quinebaug R. at Putnam, Conn.	107	331	36	554 *	3,627	3/36	37.0	9/57	Several reservoirs, diversion
Moosup R. at Moosup, Conn.	109	83.5	33	160	762	3/36	9.36	8/57	
Quinebaug R. at Jewett City, Conn.	110	711	47	1,230 *	6,930	3/36	97.4	9/57	Several reservoir
Willimantic R. nr. So. Coventry, Conn.	101	121	34	206	1,050	3/36	14.5	9/57	Staffordville reservoir
Hop R. nr. Columbia, Conn.	102	76.2	33	125	587	3/36	3.49	9/57	Boulton Lake
Natchaug R. at Willimantic, Conn.	104	169	35	292 *	1,681	3/36	11.2	9/43	Several reservoirs, diversions
Shetucket R. nr. Willimantic, Conn.	105	401	40	685 *	3,946	3/36	44.5	8/57	Several reservoirs
Yantic R. at Yantic, Conn.	111	88.6	35	155	761	3/36	5.83	9/57	
Housatonic R. nr Gt. Barrington, Mass.	182	280	52	512	2,528	3/36	75.1	9/13	
Housatonic R. at Falls Village, Conn.	183	630	53	1,050	5,291	3/36	122	10/14	Power plant
Housatonic R. at Gaylordsville, Conn.	185	994	25	1,568	6,599	1/49	222	9/58	Power plants
Still River nr. Lanesville, Conn.	186	68.5	34	118	642	10/55	15.8	9/55	
Shepaug R. nr. Roxbury, Conn.	188	133	35	238 *	1,379	3/36	8.06	9/49	Several reservoirs, diversion
Pomperaug R. at Southbury, Conn.	189	75.3	33	123	625	10/55	7.66	9/53	Lockwood Res. diversion
Housatonic R. at Stevenson, Conn.	190	1,545	37	2,508 *	12,960	3/36	301	10/59	Several reservoirs
Naugatuck R. at Beacon Falls, Conn.	191	261	43	466 *	2,920	8/55	55.3	10/30	Several reservoirs, diversion
Saugatuck R. nr. Westport, Conn.	192	59.6	-	-	825	10/55	6.94	8/57	Several reservoirs

(a) Based on observed flows except for data with asterisks (*) which have been adjusted for some effects of regulation.
(b) Based on records through Water Year 1965.
(c) Based on records through Water Year 1960.
(d) Total drainage area. (Net above gage = 4,425 sq. mi.)

Major water quality problems exist in the Merrimack River and some of its major tributaries, the upper Connecticut River below Groveton, N.H., the lower main stem Connecticut, the Boston metropolitan area, the Blackstone River and other tributaries to Narragansett Bay, and the Naugatuck River in the Housatonic Basin.

Floods. Serious flooding can occur in the Sub-region in any season. However, high spring runoff from heavy rains and melting snow combine to make this season most frequently affected. The flood of record occurred throughout most of the Sub-region in March 1936. Some of the record high discharges and their locations include: the Piscataqua River at South Lebanon, N.H., 5,490 c.f.s.; the Saco River at Cornish, Me., 45,000 c.f.s.; the Merrimack River at Plymouth, N.H., 65,400 c.f.s.; and the Connecticut River at Hartford, Conn., 313,000 c.f.s. Other record floods occurred in parts of the Sub-region in February 1886, November, 1927, July 1938, September 1938, twice in August 1955, and October 1955. The two August 1955 hurricanes occurred within a 5-day period, causing particularly high flows throughout main stem tributaries in Massachusetts and Connecticut, and many peak flow records were established, especially in the Thames and Housatonic River Basins.

The combination of meteorological effects which causes most flood - producing storms involves a persistent high pressure moisture laden area to the east of the Sub-region, circulating clockwise, accompanied by a second high pressure moisture laden area over the mid-continent, and a low between these two highs. The two high pressure areas converge, lifting warmer moist air over cold air, resulting in large amounts of rainfall. Table C-41 gives flood data for selected stations in Sub-region B, and Table C-3 (p.18) lists peak flow frequency data.

Low Flow. Severe low annual flow periods in Sub-region B in this century are 1930-1932, 1941, 1942, 1949, 1957 and 1962-1966. The Saco River at Cornish, Me., had a flow of about 60% of the long-term average in Water Year 1941, and a flow of 52% of long-term average in 1965. These are the lowest on record. The Merrimack River near Goff Falls below Manchester, N.H., experienced a record low of 44% of average in Water Year 1965, replacing the previous low of 68% in 1941. The record annual low at Dalton, N.H., on the Connecticut River, was 72% of average, also in 1965, showing the relatively low variability of flow in this area on the main stem.

Streamflow records for the White River at West Hartford, Vt., show a minimum annual of 43% in 1965, replacing the 1941 low of 60%. The Connecticut River at Thompsonville, Conn., recorded a low of 7,847 c.f.s., or 49% of average, in Water Year 1965, replacing the previous low of 10,650 c.f.s., or 67% of average, set

FLOOD DATA - SUBREGION B

Location	Map Code	Latest Data (W.Year)	Flood No. 1 Date	Peak Q. c.f.s.	Stage, ft.	$Q/(D.A.)^{.5}$	Flood No. 2 Date	Peak Q. c.f.s.	Stage, ft.	$Q/(D.A.)^{.5}$	Flood No. 3 Date	Peak Q. c.f.s.	Stage, ft.	$Q/(D.A.)^{.5}$
Presumpscot R. at Outlet of Sebago L.,Me.	40	1965	4/ 7/02	7000(a)	-	340	4/ 3/36	3790(a)	-	180	6/ 5/52	3620(a)	-	170
Saco R. nr Conway,N.H.	41	1966	3/27/53	43900	17.2	2240	10/24/59	40600	16.4	2070	3/19/36	40600	16.4	2070
Ossipee R. at Effingham, Falls,N.H.	42	1965	3/28/53	11700	11.6	640	5/12/54	6700	9.6	370	4/ 7/60	5640	9.0	310
Ossipee R. at Cornish, Me.	43	1965	3/21/36	17200	16.3	810	3/29/53	13800	13.9	650	5/11/54	7940	9.7	370
Saco R. at Cornish,Me.	44	1965	3/21,22/36	45000	21.9	1250	3/29/53	42400	20.5	1180	5/ 2/23	23000	14.7	640
Salmon Falls R. nr. S. Lebanon,Me.	47	1965	5/19/36	5490	12.3	450	5/ 9/54	4940	11.4	410	4/19/33	4090	10.0	340
Lamprey R. nr. Newmarket,N.H.	49	1965	3/20/36	5490	14.9	410	4/ 6/60	4470	11.5	330	5/11/54	4070	11.4	300
Baker R. nr. Rumney, N.H.	51	1965	11/ 3/27	25900	17.4	2170	6/15/42	21400	15.5	1790	3/18,19/36	19100	14.5	1600
Pemigewasett R. at Plymouth,N.H.	52	1965	3/19/36	65400	29.0	2620	11/ 4/27	60000	27.4	2410	10/25/59	52700	22.7	2110
Lake Winnepesaukee Outlet of L'keport,N.H.	55	1965	3/31/36	2890(a)	-	150	6/2,8/54	2520(a)	-	130	5/ 1/53	2500(a)	-	130
Merrimack R. at Franklin Jct.,N.H.	57	1965	3/19/36	83000	36.4	2140	11/ 5/27	63000	30.8	1630	9/22/38	59200	29.5	1530
N.Branch Contoocook R. nr. Antrim,N.H.	60	1965	3/19/36	5000	9.3	680	9/22/38	3640	8.4	490	4/19/33	1950	6.7	260
Warner R. at Davisville,N.H.	63	1965	3/27/53	4510	9.9	370	5/ 5/60	4380	9.8	360	6/25/44	3950	9.6	330
Blackwater R. nr. Webster,N.H.	64	1965	3/19/36	11000	11.8	970	9/22/38	6880	10.5	610	4/20/33	2950	16.4	260
Contoocook R. at Penacook,N.H.	65	1965	3/20/36	46800	14.3	1690	9/23/38	42400	13.3	1530	4/20/33	17600	7.9	640
Suncook R. at N. Chichester,N.H.	66	1965	3/19/36	12900	15.3	1030	4/ 7/23	6580	13.0	530	3/27/53	5760	12.6	460
So. Br. Piscataquog R. nr. Goffstown,N.H.	67	1965	6/25/44	4100	9.5	400	4/ 5/60	3820	9.2	370	6/15/42	3550	9.0	350
Merrimack R. nr. Goffs Falls blw Manch.,N.H.	69	1965	3/20/36	150000	35.2	2700	9/23/38	102500	25.9	1840	4/ 6/60	59000	17.4	1060
Souhegan R. at Merrimac,N.H.	71	1965	3/19/36	16900	16.2	1290	9/21/38	10800	12.8	830	4/ 8/24	9260	11.8	710
Nashua R. at East Pepperell,Mass.	73	1965	3/20/36	20900	19.1	1000	9/23/38	10200	14.1	490	6/26/44	7100	11.9	340
Merrimack R. blw Concord R. at Lowell,Mass.	76	1965	3/20/36	173000	68.4	2540	9/23/38	121100	60.6	1780	4/23/1852	108000	60.6	1590
Conn. R. at 1st Conn. Lk. nr. Pittsburg,N.H.	112	1965	6/16/43	7200	6.2	290	9/18/41	2200	4.6	240	6/ 3/47	2080	4.5	230
Conn. R. at N. Stratford,N.H.	113	1965	6/16/43	28700	14.7	1020	3/19/36	28400	14.7	1000	4/25/34	21700	12.7	770
Conn. R. nr. Dalton, N.H.	115	1965	3/20/36	118300	25.6	1240	4/ 9/28	44300	667.5	1140	4/20/33	35800	665.8	920
Ammonoosuc R. nr. Bath,N.H.	120	1965	3/18/36	27900	15.4	1400	9/21/38	26800	15.1	1350	10/25/59	23500	14.3	1180
Moose R. at St. Johnsbury,Vt.	117	1965	4/30/29	5800	8.3	510	4/25/34	5660	8.2	500	3/19/36	4780	5.7	420
Passumpsic R. at Passumpsic,Vt.	118	1965	3/18/36	16000	21.2	770	4/23/54	10900	15.7	520	4/21/50	10700	15.6	510
White R. at West Hartford,Vt.	124	1965	11/ 4/27	120000	29.3	4570	9/22/38	47600	19.3	1810	3/18/36	45400	18.9	1730
Conn. R. at White R. Jct.,Vt.	125	1965	11/ 4/27	136000	35.0	2120	3/19/36	120000	32.6	1870	3/27/13	113000	30.0	1770
Mascoma R. at Mascoma,N.H.	127	1965	3/19/36	5840	7.5	470	3/27/53	4880	6.0	390	9/22/38	4400	6.8	360
Ottauquechee R. at N. Hartland,Vt.	128	1965	11/ -/27	30400	21.5	2040	9/21/38	24400	17.7	1640	3/18/36	19200	15.6	1290
Sugar R. at W. Claremont,N.H.	129	1965	3/19/36	14000	10.9	850	9/21/38	13100	10.5	800	4/12/34	10500	9.3	640
Black R. at N. Springfield,Vt.	130	1965	9/22/38	15500	17.7	1230	3/18/36	14700	16.4	1170	6/ 1/52	13000	16.1	1030
Ashuelot R. nr. Gilsum,N.H.	137	1965	9/21/38	5220	11.2	620	3/19/36	4400	12.8	520	11/26/50	3700	9.3	440
S. Br. Ash. R. at Webb nr. Marlborough,N.H.	139	1965	9/21/38	5960	7.9	990	10/24/59	4350	7.4	730	3/18/36	3880	7.6	650
West R. at Newfane,Vt.	135	1965	9/21/38	52300	22.8	2980	11/ 3/27	45000	23.0	2560	12/31/48	39600	19.5	2260
Conn. R. at Vernon,Vt.	136	1965	3/19/36	176000	128.8	2220	9/22/38	132500	120.7	1670	4/ 5/60	107000	209.6	1350
Ashuelot R. at Hinsdale,N.H.	140	1965	3/19/36	16600	20.2	810	9/22/38	16200	11.4	790	11/ 5/27	13400	13.4	650
Tarbell Brook nr. Winchendon,Mass.	141	1965	9/21/38	2630	13.7	620	3/18,19/36	1430	12.4	330	4/ 5/60	647	10.7	150
Millers R. nr. Winchendon,Mass.	142	1965	9/22/38	8500	21.6	930	3/19/36	5530	18.3	610	4/ 5/60	2200	-	240
East Br. Tully R. nr. Athol,Mass.	145	1965	9/21/38	5140	8.6	720	3/18,19/36	3700	6.5	520	11/ 4/27	2090	5.2	290
Millers R. at Erving,Mass.	147	1965	9/22/38	29000	13.4	1500	3/19/36	19700	10.9	1020	4/13/40	7000	5.1	360
Conn. R. at Turners Falls,Mass.	148	1965	3/19/36	210000(a)	-	2480	9/22/38	174000(a)	-	2050	11/ 5/27	152000(a)	-	1800
Deerfield R. at Charlemont,Mass.	149	1965	9/21/38	56300	20.2	2960	12/31/48	42600	17.8	2240	7/ 8/15	38200	15.7	2010
Conn. R. at Montaque City,Mass.	152	1965	3/19/36	236000	49.2	2660	9/22/38	195000	44.7	2200	11/ 5/27	179000	34.1	2020
Ware River at Coldbrook,Mass.	154	1965	9/21/38	14000	32.4	1420	3/19/36	5990	29.5	610	6/25/44	2680(a)	-	270
Ware R. at Gibbs Crossing,Mass.	155	1965	9/21/38	22700	18.2	1610	8/19/55	12200	12.8	870	3/19/36	11200	12.0	790
Swift R. at West Ware,Mass.	157	1965	3/19/36	7590	15.0	550	9/22/38	5540	13.7	400	3/18/12	2390	-	170
Quaboag R. at W. Brimfield,Mass.	158	1965	8/19/55	12800	14.8	1040	9/21/38	8470	11.8	690	3/18/36	3620	8.6	300

TABLE C-41 CONT.

FLOOD DATA - SUBREGION B

Location	Map Code	Latest Data (W.Year)	Flood No. 1 Date	Flood No. 1 Peak Q. c.f.s.	Flood No. 1 Stage, ft.	Flood No. 1 Q/(D.A.)$^{.5}$	Flood No. 2 Date	Flood No. 2 Peak Q. c.f.s.	Flood No. 2 Stage, ft.	Flood No. 2 Q/(D.A.)$^{.5}$	Flood No. 3 Date	Flood No. 3 Peak Q. c.f.s.	Flood No. 3 Stage, ft.	Flood No. 3 Q/(D.A.)$^{.5}$
Chicopee R. at Ind Orchari,Mass.	159	1965	9/21/38	45200	-	1720	8/19/55	40500	22.1	1540	3/31/60	7560	10.9	290
Westfield R. at Knightville,Mass.	160	1965	9/21/38	37900	29.6	2980	3/18/36	25700	24.1	2020	11/ 3/27	16000	15.2	1260
Mid. Br. Westfield R. at Gross Hts,Mass.	162	1965	9/21/38	19900	10.6	2740	8/19/55	16500	11.3	2280	12/31/48	9600	8.6	1320
W. Br. Westfield R. at Huntington,Mass.	163	1965	8/19/55	26100	15.3	2700	9/21/38	21800	15.5	2250	3/18/36	14400	13.0	1490
Westfield R. nr. Westfield,Mass.	164	1965	8/19/55	70300	34.2	3150	9/21,22/38	55500	29.4	2490	5/18/36	48200	27.2	2160
Conn. R. at Thompson-ville,Conn.	165	1965	3/20/36	282000	16.6	2880	9/22,23/38	236000	14.4	2410	8/19/55	174000	10.9	1780
Scantic R. at Broad Brook,Conn.	167	1965	8/19/55	13300	19.9	1340	9/21/38	5130	14.4	520	3/13/36	1820	10.2	180
W. Br. Farmington R. nr. New Boston,Mass.	166	1965	8/19/55	34300	14.1	3580	9/21/38	18500	12.9	1930	12/31/48	11700	10.5	1220
Nepaug R. nr. Nepaug,Conn.	170	1965	8/19/55	10000	-	2100	(Maximum Discharge)				Other Discharges not Readily Available			
Clear Brk. nr. Collinsville,Conn.	171	1965	8/19/55	56.5	-	70	(Maximum Discharge)				-do-			
Burlington Brk. nr. Burlington,Conn.	172	1965	8/19/55	1690	9.2	830	9/21/38	676	7.2	330	12/31/48	591	6.9	290
Farmington R. at Rainbow,Conn.(b)	174	1965	8/19/55	69200	23.5	2850	8/16/55	34700	16.4	1430	9/22/38	29900	14.0	1230
Hockanum R. nr. E. Hartford,Conn.	177	1965	9/21/38	5160	13.8	600	8/19/55	2740	10.5	320	1/25/38	2140	8.8	250
Salmon R. nr. E. Hampton,Conn.	178	1965	9/21/38	12400	11.0	1210	10/16/55	9130	8.2	890	7/23/38	6300	6.5	610
Ipswich R. nr. Ipswich,Mass.	79	1965	3/15/36	2610	7.7	230	10/ 9/62	2070	7.4	190	1/29/58	1970	6.9	180
Mother Brook at Dedham,Mass.	82	1965	8/24/55	970	92.9	-	7/28/38	909	21.8(c)	-	3/19/36	900	21.4(c)	-
Charles R. at Waltham,Mass.	83	1965	3/19/36	2540	4.8	170	4/19/55	2490	5.4	170	7/26,29/38	2180	4.6	140
Taunton R. at State Farm,Mass.	86	1965	8/21/55	4010	13.0	250	12/ 8/45	3080	11.6	190	4/14/35	3060	10.7	190
Wading R. nr. Norton, Mass.	87	1965	8/20/55	1170	11.0	180	3/19/36	1030	8.8	160	6/11/31	843	9.5	130
Kette Brook at Worcester,Mass.	88	1965	8/19/55	3970	12.8	710	3/18/36	2520	8.6	450	9/12/54	1530	6.7	270
Blackstone R. at Woonsocket,R.I.	92	1965	8/19/55	32900	21.8	1610	7/24/38	15100	14.4	740	3/19/36	15000	14.4	740
Pawtuxet R. at Cranston, R.I.	95	1965	11/ 6/55	2090	9.1	150	9/13/54	2010	8.8	140	1/15/40	1960	8.2	140
Pawcatuck R. at Westerly,R.I.	99	1965	3/16/53	3510	8.8	200	9/12/54	3340	8.9	190	3/ -/36	3150	-	180
Quinebouag R. at Quinebouag,Conn.	106	1965	8/19/55	49300	19.0	3930	9/21/38	19000	16.2	1520	3/18/36	10500	13.4	840
Quinebouag R. at Putnam,Conn.	107	1965	8/19/55	48000	26.5	2640	9/21/38	20900	19.4	1150	3/19/36	17200	17.3	950
Moosup R. at Moosup, Conn.	109	1965	3/12/36	4260(d)	8.2	470	7/24/38	4100(d)	8.2	450	10/16/55	2930	7.0	320
Quinebouag R. at Jewett City,Conn.	110	1965	8/20/55	40700	29.0	1530	3/19/36	29200	24.0	1100	7/24/38	25000	22.5	940
Willimantic R. nr. So. Coventry,Conn.	101	1965	8/19/55	24200	18.7	2200	9/21/38	15500	18.1	1410	3/12/36	7880	12.2	720
Hop R. nr. Columbia, Conn.	102	1965	9/21/38	6450	16.2	740	8/19/55	5570	15.1	640	10/16/55	4820	14.2	550
Notchaug R. at Willimantic,Conn.	104	1965	9/21/38	32000(e)	16.4	2460	3/18/36	14200(f)	13.6	1090	7/22/38	9740	12.5	750
Shetucket R. nr. Willimantic,Conn.	105	1965	9/21/38	52200	27.6	2610	3/12/36	23900	18.4	1190	8/19/55	21300	17.4	1060
Housatonic R. nr. Gt. Barrington,Mass.	182	1965	1/ 1/49	12200	12.1	730	9/22/38	11520	11.7	690	3/19/36	8990	10.6	540
Housatonic R. at Falls Villiage,Conn.	183	1965	1/ 1/49	23900	22.9	950	8/19/55	22700	22.8	900	9/23/38	19900	20.7	790
Housatonic R. at Gaylordsville,Conn.	185	1965	8/19/55	51800	18.6	520	9/22/38	37000	14.5	370	1/ 1/49	32300	14.8	320
Still River nr. Lanesville,Conn.	186	1965	10/16/55	7980	14.1	960	8/19/55	3920	11.2	470	9/22/38	3590	10.9	430
Shepoug R. nr. Roxbury,Conn.	188	1965	8/19/55	30300	17.2	4360	9/21/38	10500	12.8	910	10/16/55	7760	11.5	670
Pomperoug R. at Southbury,Conn.	189	1965	8/19/55	29400	21.8	3390	10/16/55	8860	15.8	1020	9/21/38	7420	16.0	850
Housatonic R. at Stevenson,Conn.	190	1965	10/16/55	75800	24.5	1930	3/12/36	69500	23.5	1770	8/19/53	69400	23.4	1770
Naugatuck R. at Beacon Falls,Conn.	191	1965	8/19/55	106000	25.7	6550	10/16/55	30400	13.7	1880	12/31/48	28500	12.4	1760
Saugatuck R. nr. Westport,Conn.	192	1965	10/16/55	14800	15.9	1920	3/12/36	5310	11.3	690	3/13/53	4710	10.6	610

(a) Maximum daily mean discharge.
(b) Adjusted for local regulation by Farmington R. Power Co.
(c) 70.00' to be added to gage heights prior to 1953.
(d) Adjusted for regulation effects.
(e) Result of upstream release; natural peak 27,200 cfs (G.H. 15.7').
(f) Result of upstream release; natural peak 12,900 cfs Mar. 19 (G.H. 13.28').

Note: Stations are not necessarily listed in the usual downstream order. Refer to map code number sequences.

in 1941. The 1960's drought was quite severe and prolonged in the southeastern portion of Sub-region B, where flow on the Housatonic River at Stevenson, Conn., was about 60% of average during the Combined Water Years 1963, 1964 and 1965, and reached a record low of about 39% in 1965.

Ground Water. The progression of glaciers into Sub-region B, causing mechanical erosion, transport of rocks, and subsequent sedimentation and stratification of outwash streams, has left many suitable aquifers of permeable sand and gravel deposits. Glacial till deposits of unsorted rocks and pebbles, which were left during the glacial recession, are less permeable and, therefore, less suitable for aquifers. The wells in these deposits yield small amounts of ground water, which, because of their nearness to the surface, are more susceptible to contamination by pollutants, especially during dry periods.

Sandstone and shale formations also supply moderate amounts of ground water, mostly for domestic purposes. High yields have been reported locally from faulted limestone where openings have been enlarged by solution. Glacial stratified drift, lying along the principal streams and many smaller streams, supplies much of the ground water needs of the Sub-region.

The Sub-region's ground water varies considerably in hardness. Generally, the unconsolidated aquifers are softer and contain fewer objectionable constituents than the wells in calcareous rock. Ground water is suitable for most uses, except in localized areas where hardness, color, and iron and manganese content may require control. Ground water temperatures vary from about 40° F. in the north to 50° F. in southern parts of the Sub-region.

Estuaries and Coastal Areas. The coastal and estuarine area is broadly defined as that zone bounded by the edge of the continental shelf on its seaward side and a line joining the upper reaches of river mouths, where detectable amounts of seawater can be traced on its landward side.

The Sub-region's coastal states (Maine, New Hampshire Massachusetts, Rhode Island and Connecticut), along approximately 1,500 miles of shoreline, possess a broad continental shelf and numerous estuaries. While the origin of continental shelves is still open to speculation, the estuaries are simply inundated river valleys caused by subsidence of the coastal area, a rise in sea level, or both.

Although the continental margin of the northeastern United States has been slowly subsiding since the Cretaceous Period, various minor changes of much shorter time scale have occurred. These relatively recent changes, such as the rise in land mass after the retreat of glaciers (glacial rebound) and the concurrent rise in sea level, have created many of the Sub-region's present coastline features. Even finer scale features are the result of local geology and the physical forces of nature such as waves, winds and currents acting to modify the existing geomorphology.

Where glaciers have deposited substantial amounts of unconsolidated material, in the form of terminal moraine, glacial till or outwash plains, significant erosion and reshaping of these deposits have taken place since the retreat of glaciers approximately 15,000 years ago. The coastline of Cape Cod, an area completely composed of glacial deposits was in some places more than 2 miles east of the present shore and the sediments eroded have been redistributed through the action of longshore currents. Areas of glacial debris deposits are most likely to have extensive sandy beaches for example, the southern shore of Connecticut, Cape Cod, Martha's Vineyard, Nantucket Island (Massachusetts), and Rhode Island. Areas of lesser deposition of unconsolidated glacial material, generally occurring northward from Cape Ann, Massachusetts, possess stretches of coastline where bedrock is exposed, or cobble beaches are present more frequently, because most of the glacial material has been eroded and redistributed. On this type of coastline, beaches are found within the numerous sheltered bays and as bars extending from eroded headlands.

Of the many physical factors influencing erosion, the most important are wind-generated waves which are directed towards the coast at an angle to the shoreline. The actual breaking of waves provides most of the erosive force, while the alongshore component of the transfer of forward momentum of the waves establishes the longshore current or the direction of littoral drift, and the motive force for redistributing the sediments.

Since the coastlines of Sub-region B are oriented in a SW-NE direction, waves, generated offshore by the predominant westerly winds, have little effect on coastal processes. Winds from the southerly quadrants are next in order of frequency and the predominant littoral drift is naturally from south to north, except for alterations in this pattern due to local geology. However, the major changes in beaches are due to occasional hurricanes from the south and the more frequent winter storms know as northeasters. Thus, although the predominant littoral drift based on percentage of time is from south to north, the net littoral drift is from north to south or from east to west along the Connecticut Coast, solely due to the effect of infrequent destructive winter storms.

Tides are important as agents of erosion and transport in narrow bays or estuaries. Mean tidal ranges at selected locations are:

Location	Mean Range (ft.)
Portland, Me.	9.0
Merrimack River Entrance	8.3
Boston, Mass.	9.5
Provincetown, Mass.	9.1
Newport, R.I.	3.5
New London, Conn.	2.6
Bridgeport, Conn.	6.7

Water Availability Analysis

Evapotranspiration. The average annual evapotranspiration in Sub-region B is approximately 21 inches, varying from almost 25 inches near the coast to about 15 inches in the northern portion of the Connecticut River Basin. Normal July evapotranspiration is between 5 and 5.5 inches and reservoir surface evaporation for the same month is between 4 and 4.5 inches. The normal annual precipitation for the Sub-region is 44 inches and, assuming no change in ground water storage, subtracting the average annual runoff of about 23 inches, results in an average annual evapotranspiration of 21 inches. Average annual net losses from reservoir surfaces as the evaporation minus the evapotranspiration from the area a reservoir replaces, would be about 5 inches. This value is subject to wide seasonal and geographic variation. However, there may even be gains on a seasonal, or other short term basis, due to the interception of precipitation directly on the lake surface instead of first seeping into the ground.

Streamflow Simulation. The method used to estimate missing monthly streamflow through 1967 is described in Chapter 3 for the key stations shown in Table C-42. The stations were grouped for correlation analysis according to the numeral shown in the left hand column of the Table. The grouped stations were used for the generation of synthetic streamflow traces as well as the estimation of missing flows and extension of observed records. All observed records were extended to 69 years. Ten 100-year periods were generated for each station. The stations cover a total drainage area of 19,580 square miles. A summary of the maximum and minimum occurrences for the historic record and for all of the generated records is given in Table C-43 for 1-, 6- and 54-month volumes at selected stations. Schematic diagrams of the key stations, showing relative location and incremental drainage areas, are shown on Figure C-32.

Yield-Storage Relationships. Relationships between yield, storage and shortage index were derived by the method discussed in

TABLE C-42
KEY STREAMFLOW STATIONS
SUB-REGION B

Analysis Group	NAR Number	Station	Drainage Area (Sq. Mi.)	Approx. Yrs. of Observed Record
III	201	Housatonic R. at Falls Village, Conn.	632	55
III	252	Housatonic R. at Stevenson, Conn.	1,545	39
I	253	Connecticut R. at North Stratford, N.H.	799	37
I	254	Connecticut R. nr Dalton, N. H.	1,514	40
I	205	White R. at West Hartford, Vt.	690	52
I	256	Connecticut R. at White R. Junction, Vt.	4,092	55
I	257	Connecticut R. at Vernon, Vt.	6,266	23
III	258	Deerfield R. at Charlemont, Mass.	362	53
I	259	Connecticut R. nr Montague City, Mass.	7,865	63
III	260	Ware River at Gibbs Crossing, Mass.	199	55
III	261	Chicopee R. at Indian Orchard, Mass.	688	39
III	262	Westfield R. nr Westfield, Mass.	497	53
I, III	263	Connecticut R. at Thompsonville, Conn.	9,661	39
III	264	Farmington R. at Rainbow, Conn.	591	39
IV	215	Shetucket R. nr Willimantic, Conn.	401	43
IV	216	Quinebaug R. at Jewett City, Conn.	711	49
IV	267	Pawcatuck R. at Westerly, R. I.	295	27
IV	268	Taunton R. at State Farm, Mass.	260	38
II	219	Pemigewasset R. at Plymouth, N. H.	622	64
II	220	Merrimack R. at Franklin Junction, N.H.	1,507	61
II	221	Contoocook R. at Penacook, N. H.	766	39
II	222	Merrimack R. nr Goffs Falls below Manchester, N. H.	3,092	30
II	223	Souhegan R. at Merrimack, N. H.	171	58
II	274	Nashua R. at East Peperell, Mass.	433	32
I,II,III,IV	275	Merrimack R. blw Concord R. at Lowell, Mass.	4,635	44
IV	226	Lamprey R. nr Newmarket, N. H.	183	32
IV	227	Saco R. nr Conway, N. H.	386	43
IV	228	Saco R. at Cornish, Me.	1,298	51

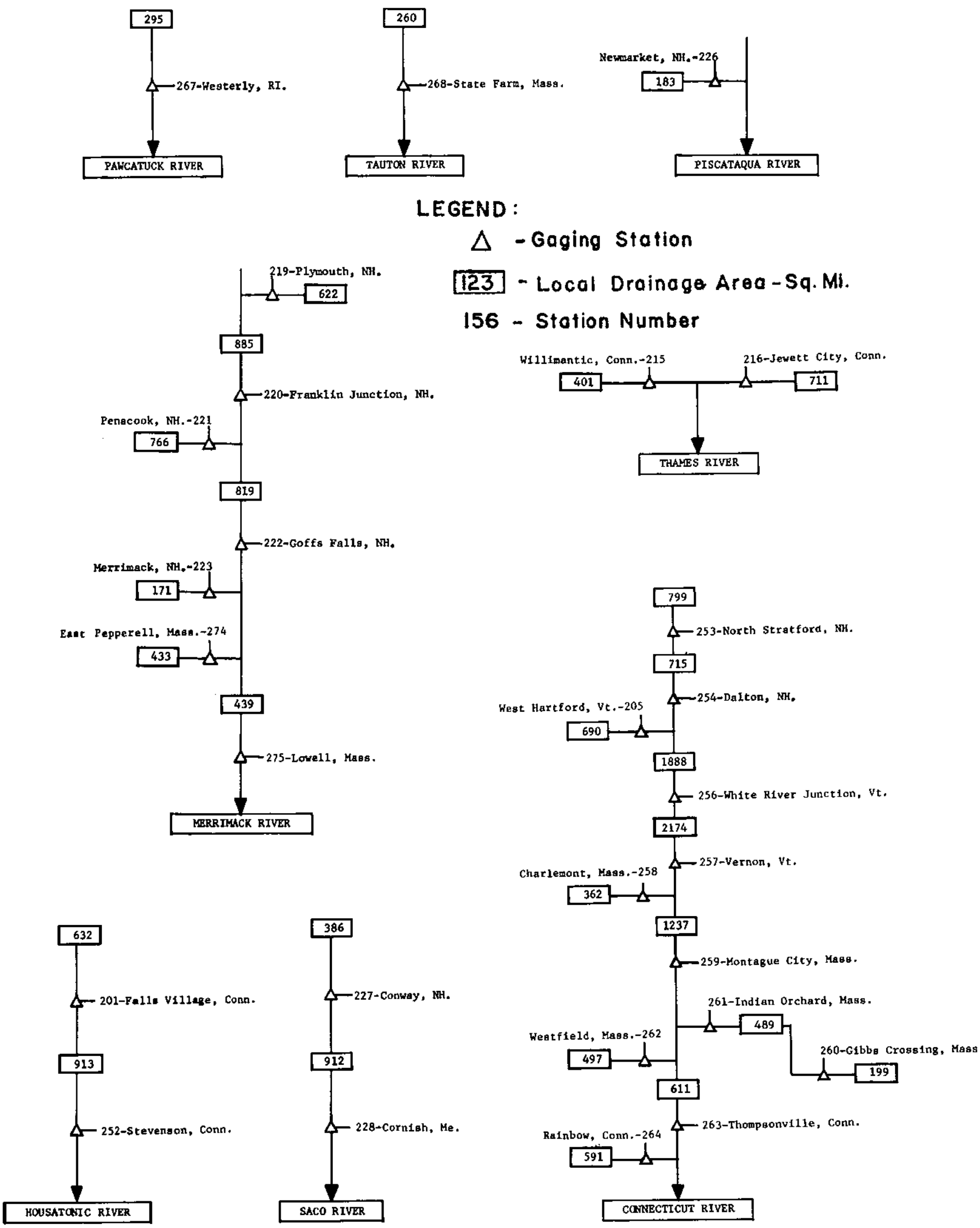
TABLE C-43
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION B
(Cubic feet per second)

Station No.			1 Month Max	1 Month Min	6 Months Max	6 Months Min	54 Months Max	54 Months Min
219		Hist.	10,640	107	20,818	1,302	94,815	52,029
	Gen.	High Pd.	12,248	106	30,215	1,702	108,141	54,643
		Low Pd.	7,548	36	22,486	923	94,636	42,478
221		Hist.	9,196	87	16,809	869	91,479	42,637
	Gen.	High Pd.	24,816	110	41,844	1,237	122,897	45,519
		Low Pd.	7,494	45	21,190	774	87,578	34,001
223		Hist.	2,278	8	3,969	150	21,247	8,684
	Gen.	High Pd.	2,505	13	8,546	191	28,021	10,440
		Low Pd	1,798	6	4,769	68	21,821	7,469
275		Hist.	46,351	886	99,488	8,259	543,384	252,271
	Gen.	High Pd.	93,222	987	188,657	10,484	660,669	292,288
		Low Pd	36,988	738	113,300	6,349	496,570	230,576
252		Hist.	21,961	152	39,291	1,970	190,259	77,773
	Gen.	High Pd	68,998	212	138,884	2,538	273,398	98,529
		Low Pd	11,807	139	40,668	1,590	181,565	82,350
258		Hist.	5,502	16	11,184	492	59,334	32,415
	Gen.	High Pd.	13,901	25	27,183	776	74,027	33,592
		Low Pd.	4,953	4	14,287	556	61,319	27,813

TABLE C-43 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION B

Station No.			1 Month		6 Months		54 Months	
			Max	Min	Max	Min	Max	Min
263		Hist.	113,166	1,730	211,403	20,931	1,101,453	602,092
	Gen.	High Pd.	180,386	2,068	420,394	23,757	1,283,012	700,954
		Low Pd.	87,450	979	251,571	19,036	1,118,526	597,424
215		Hist.	3,949	44	10,357	454	51,943	21,055
	Gen.	High Pd.	9,395	43	18,592	626	61,179	26,694
		Low Pd.	3,471	22	9,962	426	46,398	20,304
268		Hist.	2,261	42	7,429	465	36,513	16,778
	Gen.	High Pd.	17,088	42	26,240	533	53,340	19,417
		Low Pd.	1,863	24	6,220	408	35,214	16,217
226		Hist.	1,866	3	4,222	156	21,266	9,943
	Gen.	High Pd.	2,948	4	6,265	156	23,566	10,402
		Low Pd.	1,910	2	4,220	84	19,041	7,925
228		Hist.	18,841	406	40,522	3,709	202,248	103,092
	Gen.	High Pd.	35,877	619	57,093	7,281	223,234	295,956
		Low Pd.	13,784	178	37,345	2,919	186,578	89,441

FIGURE C-32
SCHEMATIC DIAGRAM
KEY STREAMFLOW STATIONS
SUB-REGION B



Chapter 3. The streamflow stations used are shown in Table C-42. A comparison of results in terms of historic and synthetic storage requirements for selected shortage criteria and demand rates is given in Table C-44. It is noted that for the demand rates of 60% and 80% of average annual flow, the synthetic storage requirement is generally greater than the historic requirement in the northern section of the Sub-region, and the historic requirements are substantially greater in some of the southern portions. Yield-storage relationships for the Westfield River near Westfield, Mass., are given in Figure C-33 as a sample of the graphic format adopted for use.

Minimum Flow. For the purposes of plan formulation, Subregion B was divided into five Areas, and further into 13 Sub-areas. The existing minimum flow for each Sub-area was derived by computing the monthly flow from the historic record for a shortage index of 0.01. An adjustment, based on the ratio of the mean seven-day flow during the dry season to the mean monthly flow, was applied to obtain the seven-day flow for each Sub-area. This methodology is described in Chapter 3. Table C-45 lists the minimum flows, for a shortage index of 0.01, for the Sub-areas in Sub-region B. The adopted seven-day minimum flows are considered to have recurrence intervals of approximately 50 years.

An analysis of the yield of the Metropolitan District Commission system was made separately, based on information developed in the draft "Feasibility Report on Alternative Regional Water Supply Plans for Southeastern New England," prepared in November 1969 by the U.S. Army Corps of Engineers' New England Division for the Northeaster United States Water Supply Study.

The system yield is based on storage of flow from the drainage area above Quabbin Reservoir in Area 8, diversion of excess flow from the Ware River in Area 8, and storage in Wachusett Reservoir in Area 7. Since Quabbin Reservoir is more than adequate to control the average annual runoff from the drainage area upstream, and yield from the Ware River is not a result of impoundment, the net yield (195 m.g.d.) from these two elements, as reported in the referenced draft report, would not be inconsistent with the criteria of the NAR Study. The net yield of 95 m.g.d. given for Wachusett Reservoir, agrees reasonably well with computations made under the yield-storage criteria of the NAR Study.

For the purposes of NAR supply analyses, it was assumed that the total MDC yield of 290 m.g.d. was available for use in Area 9. It should be noted that, in actuality, approximately 10% is used locally in Area 7 and 8.

The above minimum flow and reservoir yield data have been used in studies of existing and practical resource development covered in Appendix E and in connection with the NAR Supply Model analyses.

TABLE C-44

STORAGE REQUIREMENT IN AF/SQ. MI. FOR INDICATED PERCENTAGES OF AVERAGE FLOW

SUBREGION B.

Station	D.A. SQ.MI.	AVERAGE FLOW.CFS.	S.I. = 0.0 HISTORIC 20%	S.I. = 0.0 HISTORIC 40%	S.I. = 0.0 HISTORIC 60%	S.I. = 0.0 HISTORIC 80%	S.I. = 0.01 H 20%	S.I. = 0.01 S 20%	S.I. = 0.01 H 40%	S.I. = 0.01 S 40%	S.I. = 0.01 H 60%	S.I. = 0.01 S 60%	S.I. = 0.01 H 80%	S.I. = 0.01 S 80%	S.I. = 0.10 SYNTHETIC 20%	S.I. = 0.10 SYNTHETIC 40%	S.I. = 0.10 SYNTHETIC 60%	S.I. = 0.10 SYNTHETIC 80%	Historic Rec. (Actual & Estimated) yrs.
Saco R. nr. Conway, N.H.	386	950	-	200	500	1,120	-	-	150	170	425	440	920	1,500	-	96	310	800	69
Saco R. at Cornish, Me.,Lcl	912	1,740	15	135	430	990	-	-	97	105	325	250	860	780	-	58	165	470	69
Saco R. at Cornish, Me.	1,298	2,688	-	125	450	1,050	-	-	100	92	350	300	900	940	-	59	200	530	69
Lamprey R. at Newmarket,N.H.	183	268	66	170	430	1,020	54	57	150	165	370	370	930	1,070	34	108	240	660	69
Pemigewasset R. at Plymouth,N.H.	622	1,352	48	200	390	850	25	-	150	180	350	460	720	1,500	-	105	315	900	69
Merr. R. at Franklin Jct.,N.H.,Lcl.	885	1,408	-	75	340	940	-	-	38	27	280	128	820	550	-	-	65	310	69
Merr. R. at Franklin Jct.,N.H.	1,507	2,758	-	88	310	870	-	-	53	60	230	230	720	820	-	-	130	470	69
Contoocook R. at Penacook,N.H.	766	1,236	-	215	600	1,160	-	-	160	150	540	460	1,050	1,300	-	98	295	860	69
Merr. R. nr. Goffs Falls blw M'chester,N.H.,Lcl.	819	1,118	80	220	550	1,330	64	63	190	230	520	510	1,140	1,140	36	145	375	700	69
Merr. R. nr. Goffs Falls blw M'chester,N.H.	3,092	5,096	-	120	440	950	-	-	90	112	360	300	850	1,060	-	48	190	660	69
Souhegan R. at Merrimack,N.H.	171	280	-	260	680	1,350	-	-	230	190	600	520	1,220	1,600	-	140	370	1,100	69
Nashua R. at E. Pepperell,Mass.	* 316	688	-	410	1,200	2,350	-	-	345	185	1,130	550	2,300	1,570	-	110	355	1,170	69
Merr. R. blw Concord R. at Lowell Mass.,Lcl.	* 846	1,246	87	260	735	1,860	75	58	235	167	690	410	1,780	1,040	39	117	230	710	69
Merr. R. blw Concord R. at																			
Pawcatuck R. at Westerly,R.I.	295	550	-	160	340	1,000	-	-	115	115	270	260	910	800	-	70	185	510	69
Taunton R. at State Farm,Mass.	260	476	35	175	475	1,120	23	23	135	140	400	340	1,000	1,130	-	85	220	650	69
Shetucket R. nr. Williamantic,Conn.	401	664	60	180	430	1,210	50	44	155	155	360	310	1,100	1,100	17	110	210	640	69
Quinebaug R. at Jewett City,Conn.	711	1,194	45	160	400	1,000	26	23	140	120	360	290	920	960	-	85	205	520	69
Conn. R. at N. Stratford,N.H.	799	1,604	36	150	350	550	21	20	120	80	275	275	480	620	-	50	170	420	69
Conn. R. nr. Dalton, N.H.,Lcl.	715	1,316	19	140	335	590	13	15	92	74	275	240	520	700	-	40	150	450	69
Conn. R. nr. Dalton, N.H.	1,514	2,920	18	150	335	520	12	-	95	72	260	240	450	640	-	46	150	400	69
White R. at W. Hartford,Vt.	690	1,164	46	155	420	1,000	27	24	135	115	360	340	890	850	-	80	220	560	69
Conn. R. at White R. Jct.,Vt.,Lcl.	1,888	2,970	20	98	230	580	14	15	78	88	190	225	490	600	-	48	150	360	69
Conn. R. at White R. Jct.,Vt.	4,092	7,050	-	105	260	550	-	-	78	72	215	225	450	510	-	37	140	360	69
Conn. R. at Vernon,Vt.,Lcl.	2,174	3,378	70	205	480	1,000	52	52	165	170	420	300	900	730	29	120	220	470	69
Conn. R. at Vernon,Vt.	6,266	10,424	16	120	275	700	10	-	92	75	225	240	560	600	-	40	155	380	69
Deerfield R. at Charlemont,Mass.	362	875	100	290	560	1,080	74	60	235	235	480	560	940	1,400	34	165	400	1,000	69
Conn. R. nr. Montaque City, Mass.	7,865	13,516	18	125	310	790	10	-	95	75	250	240	660	640	-	42	160	370	69
Ware R. at Gibbs Crossing,Mass.	199	318	54	230	690	1,400	39	39	175	145	640	320	1,380	990	18	105	240	620	69
Chicopee R. at Indian Orch., Mass.,Lcl.	489	763	72	190	530	1,250	57	46	165	150	480	280	1,200	795	24	100	190	540	69
Westfield R. nr. Westfield,Mass.	497	935	47	195	570	1,350	32	29	160	155	500	440	1,310	1,120	11	105	270	770	69
Conn. R. at Thompsonville, Conn.,Lcl.	1,848	3,098	89	190	660	1,300	66	-	160	160	595	300	1,250	820	-	110	200	540	69
Conn. R. at Thompsonville, Conn.	9,661	16,192	15	125	320	850	-	-	98	80	260	210	740	520	-	39	145	330	69
Farmington R. at Rainbow,Conn.	591	1,073	37	165	590	1,470	21	14	135	140	530	330	1,310	1,120	-	95	235	670	69
Housatonic R. at Falls Village, Conn.	632	1,052	-	170	540	1,250	-	-	125	115	440	315	1,160	860	-	69	200	560	69
Housatonic R. at Stevenson,Conn, Lcl.	913	1,488	70	200	580	1,350	50	40	165	150	520	290	1,280	870	23	102	230	540	69
Housatonic R. at Stevenson,Conn.	1,545	2,538	50	185	560	1,310	32	27	145	130	500	350	1,200	860	12	80	220	560	69

H = Historic Record
S = Synthetic Rec. Avg. of 10 periods @ 100 yrs. ea.
Lcl = local area above station
S.I. = Shortage Index
* Net. D.A. - adjusted for 210 sq. Mi. diverted to Metropolitan District Commission

FIGURE C-33. SAMPLE YIELD-STORAGE CURVES - SUB-REGION B

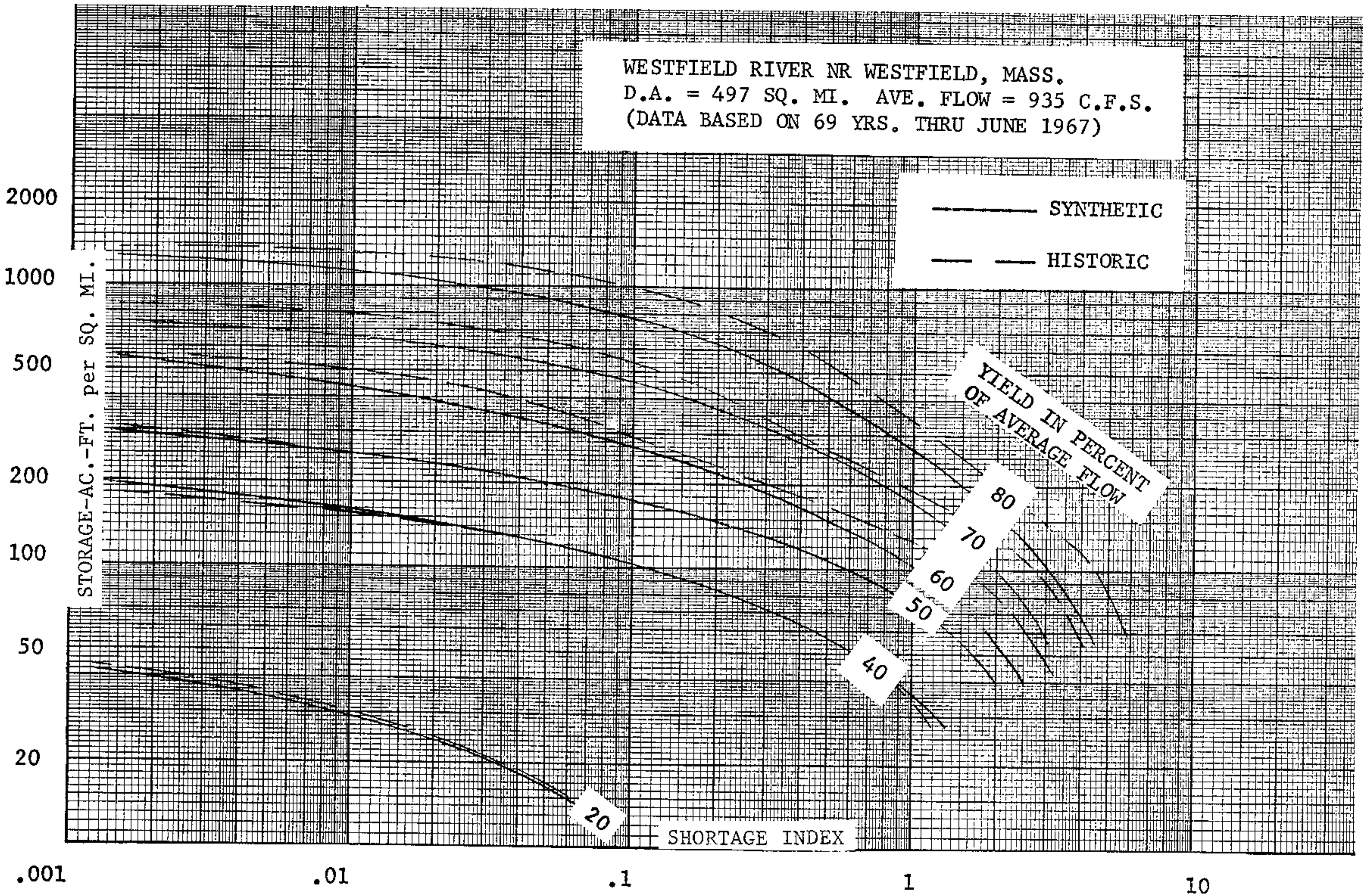


TABLE C-45
EXISTING MINIMUM STREAMFLOW - SUB-REGION B
(Cubic feet per second)

	MONTHLY	7-DAY
Sub-area 6a	350	250
Sub-area 6b	610	490
Sub-area 6c	210	160
AREA 6	1,170	900
Sub-area 7a	920	550
Sub-area 7b 1/	440	270
AREA 7	1,360	820
Sub-area 8a 2/	750	440
Sub-area 8b	1,330	680
Sub-area 8c 3/	1,190	800
Sub-area 8d	450	290
AREA 8	3,720	2,210
Sub-area 9a 4/	830	510
Sub-area 9b	950	555
AREA 9	1,780	1,065
Sub-area 10a	270	140
Sub-area 10b	540	345
AREA 10	810	485
SUB-REGION B 2/	8,840	5,480

1/ Does not include 150 c.f.s. developed for export.
2/ Includes 70 c.f.s. (Monthly) and 40 c.f.s. (7-day) from contributing drainage area in Canada.
3/ Does not include 300 c.f.s. developed for export.
4/ Does not include 450 c.f.s. which can be imported.

SUB-REGION C

Sub-region C includes all rivers in New York State which drain into the St. Lawrence River east of the United States-Canadian border, Lake Champlain drainage in New York and Vermont, the Hudson River and its tributaries, the New York City metropolitan area and Long Island. Areas and Sub-areas are shown in Figure C-1.

The Sub-region's average annual precipitation is about 41 inches with little seasonal variation. Mean annual snowfall varies from about 24 inches along the South Shore of Long Island to more than 100 inches in the Adirondack and Catskill Mountain Ranges. Transcontinental and tropical storms often cause periods of excessive rainfall. A severe four- or five-day storm may cause about 25% of the total annual precipitation in the lower part of the Sub-region.

Mean annual temperatures range from 40° F. in the north to about 50° F. in the south. Average surface wind velocities vary from 8 to 12 m.p.h., generally from the west except where shifted by major river valleys. Average annual lake evaporation is about 27 inches, and average annual evapotranspiration ranges from about 15 inches in the north to from 20 to 25 inches in the south.

Annual runoff in the Sub-region averages about 20 inches. There is fairly high runoff in the northern portions, compared to the southern portions where annual surface runoff in some locations, such as Long Island, is less than 10 inches. The most serious flooding occurs in the Hudson Basin, usually as a result of a combination of heavy spring rainfall and snowmelt.

Wells in glacial deposits are often capable of supplying as much as 1,000 g.p.m. in the northern part of the Sub-region. Ground water resources in the coastal plain of Long Island are among the most productive in the entire NAR, supplying more than 300 m.g.d. in 1960. Surface waters are generally soft, and low in dissolved solids concentrations.

The Long Island coastal area and the Hudson River Estuary are important to many of the Sub-region's water resources needs. The pollution of the estuary is well advanced and the water is often unusable, even for industrial purposes.

CLIMATE AND METEOROLOGY

Meteorologic Records

The network of meteorologic stations in Sub-region C is adequate for analyzing its climatology. The length of records at many stations provides statistically valid data from which trends may be extrapolated, since many records are more than 50 years, and some 100 years or more, in length. Figure C-34 shows the locations of those stations referred to in this Appendix.

Precipitation

The Sub-region's average annual precipitation is about 41 inches, ranging from about 28 inches in the Lake Champlain Valley to some 60 inches in the Catskill Mountains. A minimum annual precipitation of 19.1 inches was recorded at the Chazy 3E station near the northern most border of the Sub-region, immediately west of Lake Champlain in New York State, and a maximum of about 77 inches was recorded at Slide Mountain in the Catskills in 1955. The Sub-region receives about 10.5 inches of precipitation during the spring and fall, about 9 inches during the winter and 11.5 inches during the summer. Table C-46 gives precipitation data for selected stations in Sub-region C.

The mean annual snowfall varies from about 100 inches and more in the northern Adirondack Mountains and portions of the Catskill Mountains, to about 20 inches along the South Shore of Long Island. Approximately 20% to 30% of the annual precipitation in the upper Hudson River Basin is snow, as is from 10% to 20% in the lower Hudson Basin. Snowfall comprises a good part of the precipitation in Area 11, and the average water content of snow cover is 5 inches in March. Table C-47 lists snowfall data for selected stations in the Sub-region.

General storms covering large areas of the Sub-region are of the transcontinental or tropical types. Transcontinental storms, which come from the western states or from the Fulf of Mexico area, usually occur in the spring, while tropical storms generally occur in the fall or early winter. Thunderstorms and cloudbursts cover less extended areas and usually occur during the summer. A maximum daily value of about 6.5 inches of precipitation was recorded in Ellenville, N.Y., on October 16, 1965. During two successive hurricanes in August 1955, the entire southeastern New York area received from 2 to 8 inches of rainfall.

The drought of the early-1960s had serious effects in many parts of Sub-region C. This was particularly so in the southern half, where accumulated departures from normal precipitation were from 37 to 57 inches between October 1961 and August 1966. The percentage of mean precipitation during this period ranged from 73% to 82% in southeastern New York. During the drought of the 1930s, this Sub-region received about 82% of mean rainfall in 1930 and 90% in 1934.

TABLE C-46

PRECIPITATION DATA -SUBREGION C (in inches)

Station	Map Code	Years (c) of Record	Elevation ft.,m.s.l.	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Annual (c)
					Monthly Data												
Newport,Vt.	2	35	766	Max(a)	5.37	4.46	4.58	4.97	5.69	6.53	6.88	7.37	8.48	6.90	5.80	4.70	
				Min(a)	0.64	0.80	0.97	0.90	1.20	0.36	1.21	1.59	1.27	1.19	0.66	0.88	
				Mean(a)	2.52	2.28	2.44	2.94	3.09	3.76	4.14	3.37	3.65	3.18	3.04	2.50	36.88(a)
Rutland,Vt.	5	49	620	Max(a)	4.24	4.35	5.37	5.93	8.02	7.96	10.17	7.64	9.75	5.75	6.36	3.87	
				Min(a)	0.82	0.88	0.92	0.45	1.81	0.16	0.45	0.53	0.71	0.46	0.86	0.69	
				Mean(a)	2.55	2.06	2.52	2.94	3.61	4.07	4.42	3.32	3.81	2.94	3.16	2.31	37.71(a)
Lake Placid Club,N.Y.	9	59	1,880	Max(a)	5.01	4.97	6.90	5.27	6.49	7.39	8.60	7.18	8.06	7.08	5.52	6.22	
				Min(a)	1.71	1.73	1.17	0.61	1.04	1.22	1.27	.87	1.27	0.55	1.00	1.01	
				Mean(a)	3.13	2.97	3.24	2.70	3.25	3.67	3.96	3.41	3.74	2.92	2.98	3.19	39.16(a)
Burlington WB. P.,Vt.	3	124	332	Max(a)	7.52	4.18	4.53	5.83	9.85	9.92	8.48	11.54	9.85	8.11	10.13	5.29	
				Min(a)	0.42	0.18	.13	.47	T	1.09	.58	.48	.68	.15	.52	.31	
				Mean(a)	1.95	1.79	2.11	2.63	2.99	3.49	3.85	3.37	3.31	2.97	2.62	2.13	33.21(a)
Little Falls City Res,N.Y.	16	69	900	Max(a)	5.26	4.95	6.58	5.20	7.21	7.04	9.33	7.63	8.86	6.90	5.94	5.99	
				Min(a)	.88	.64	.68	1.74	.99	.75	1.12	1.50	.60	1.11	1.18	.73	
				Mean(a)	2.85	2.30	2.82	3.37	3.64	3.92	4.51	3.93	4.36	3.56	3.22	2.83	41.31(a)
Hope,N.Y.	206	29	950	Max(a)	7.57	5.05	8.65	5.81	7.83	7.61	10.72	8.39	9.17	10.11	8.17	8.54	
				Min(a)	1.16	1.04	1.11	1.36	.80	.68	1.44	.94	.12	1.26	1.83	.88	
				Mean(a)	3.84	3.36	3.83	3.79	3.62	3.74	4.46	3.53	4.07	3.68	4.08	3.94	44.72
Albany WB, City,N.Y.	19	140	19	Max(a)	4.59	3.83	6.48	5.57	7.32	7.40	8.41	8.26	10.41	7.46	5.41	6.30	
				Min(a)	.80	.82	1.02	.72	1.11	1.33	1.72	.66	1.34	.89	1.02	.73	
				Mean(a)	2.51	2.26	2.86	2.90	3.62	3.74	4.29	3.30	4.00	2.84	2.90	2.73	37.95(a)
Prattsville,N.Y.	23	18	1,165	Max(b)	4.74	4.02	5.01	4.33	6.04	6.16	7.60	11.98	3.98	11.25	5.74	5.14	
				Min(b)	.92	.86	1.29	2.08	1.41	1.48	1.44	1.62	.93	1.29	1.63	1.23	
				Mean(b)	2.93	2.67	3.04	2.93	3.66	3.30	3.56	3.56	2.81	3.70	3.28	3.54	38.98(b)
Grahamsville, N.Y.	25	25	900	Max(b)	6.16	5.59	7.44	7.41	6.20	6.52	7.81	14.12	7.74	12.14	7.19	7.63	
				Min(b)	.94	2.26	1.34	2.70	.88	.95	.85	.84	.61	.79	1.82	.94	
				Mean(b)	3.84	3.60	3.71	4.47	3.91	3.50	4.28	4.03	3.75	4.05	4.29	4.16	47.59(b)
Poughkeepsie, N.Y.	26	63	103	Max(a)	6.42	4.58	7.11	7.57	7.49	6.38	10.77	11.50	9.89	9.99	8.31	7.40	
				Min(a)	.73	1.33	.95	.78	1.18	.56	.60	.61	.78	.89	.76	.51	
				Mean(a)	2.89	2.45	3.09	3.65	3.57	3.48	4.13	3.89	3.67	3.04	3.35	3.00	40.21(a)
West Point,N.Y.	28	115	320	Max(a)	6.64	5.22	8.85	9.47	7.08	6.52	10.21	11.74	10.74	12.75	8.30	9.51	
				Min(a)	.74	1.77	1.77	1.48	1.42	.88	1.36	1.18	.42	.80	.70	.76	
				Mean(a)	3.34	2.96	4.16	4.08	4.20	3.85	4.40	4.08	4.18	3.56	4.10	3.80	46.71(a)
White Plains AP,N.Y.	30	22	397	Max(b)	8.05	5.52	11.44	9.43	8.36	5.39	7.38	13.13	8.12	13.85	7.34	7.34	
				Min(b)	.44	2.30	2.71	2.46	1.57	.06	1.18	1.71	1.13	.49	.84	.49	
				Mean(b)	3.80	3.75	5.28	4.75	4.26	2.59	4.02	5.40	3.51	4.42	4.79	4.54	51.21(b)
NYC Central Park,N.Y.	31	22	132	Max(b)	5.98	4.47	8.76	6.14	7.62	5.25	8.29	10.86	10.30	6.87	7.19	5.72	
				Min(b)	.77	1.38	1.99	1.43	1.18	.02	.51	1.84	.60	.94	.96	.25	
				Mean(b)	3.32	3.25	3.03	3.45	3.61	3.44	4.05	4.41	3.73	3.17	3.36	3.29	44.68(b)
Riverhead Research,N.Y.	33	28	100	Max(b)	7.65	6.32	8.68	6.25	6.54	6.88	8.00	12.77	11.73	8.20	8.42	7.57	
				Min(b)	.60	1.74	2.07	1.07	.86	.03	.50	.91	.74	.55	.99	.67	
				Mean(b)	3.72	3.36	4.29	3.63	3.52	2.81	3.39	4.48	3.39	3.49	4.66	3.94	44.68(b)
Orient 2E,N.Y.	34	20 (thru 1960)	10	Max(b)	7.39	5.37	8.55	6.23	6.86	5.47	7.02	10.75	8.58	8.61	9.42	6.40	
				Min(b)	.78	1.43	1.76	1.05	.72	.04	.56	.91	.52	.46	.93	.78	
				Mean(b)	3.63	3.08	4.02	3.54	3.31	2.00	3.02	4.22	2.88	3.10	4.54	3.75	41.09(b)

(a) Data based on period 1931-1960
(b) Data based on period of record thru 1960.
(c) Data based on period of record thru 1965 except as otherwise noted.

TABLE C-47

SNOW DATA - SUBREGION C

Station	Map Code	Years of Record	Elevation ft.,m.s.l.	Mean Snowfall in Inches (a)												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Newport,Vt.	2	32	766	18.7	19.4	15.3	4.2	0.2	0	0	0	T	0.4	7.4	15.0	80.6
Enosburg Falls,Vt.	1	62	422	23.7	23.4	18.7	5.7	0.1	T	0	0	T	1.0	10.5	19.9	103.0
Chasm Falls,N.Y.	8	26	1,030	24.9	28.4	20.1	5.9	0.2	T	0	T	T	1.5	10.5	26.6	118.1
Canton,N.Y.	200	51	400	15.5	15.1	12.5	3.9	0.1	0	0	0	T	1.0	7.3	14.9	70.3
Tupperlake S'mnt., N.Y.	212	38	1,680	19.6	19.7	16.2	5.4	0.2	T	0	T	T	1.3	9.5	17.0	88.9
Burlington,Vt.	52	22	332	16.8	17.2	11.4	2.0	T	0	0	0	T	0.1	5.7	14.9	68.1
Barre-Mtplr.,Vt.	61	19	1,122	21.4	24.4	16.6	5.5	T	0	0	0	T	0.7	7.4	18.4	94.4
Cornwall,Vt.	55	23	340	15.6	14.5	13.1	2.8	0.2	0	0	0	T	0.3	4.4	12.5	63.4
Rutland,Vt.	56	30	620	14.9	13.9	11.2	3.2	0.2	0	0	0	T	0.1	4.3	8.2	56.0
Speculator,N.Y.	11	12	1,760	19.9	23.7	19.9	5.5	T	T	T	0	T	0.2	8.1	15.6	92.9
Gloversville,N.Y.	203	61	780	20.7	21.7	14.6	4.0	0.1	T	T	T	T	0.4	5.3	14.9	81.7
Utica FAA,A.P.,N.Y.	15	10	718	16.6	15.6	13.6	1.7	T	T	T	0	T	0.3	6.5	13.1	67.4
Bennington,Vt.	62	14	670	15.6	14.1	12.3	2.0	0.2	0	0	0	0	0.3	2.1	10.8	57.4
Albany,A.P.,N.Y.	19	23	275	16.2	13.4	11.6	2.6	0.2	T	T	T	0	0.1	3.6	10.1	57.8
Ellenville,N.Y.	27	13	350	10.7	12.5	10.1	2.2	0	T	T	0	0	T	1.6	8.5	45.6
Poughkeepsie A.P., N.Y.	26	12	154	9.5	7.5	7.4	1.3	T	0	T	0	0	T	1.2	6.3	33.2
NYC Central Park,N.Y.	31	41	132	6.8	8.1	4.6	0.9	T	0	T	0	0	T	0.9	5.8	27.1
Riverhead Research,N.Y.	33	22	100	6.1	5.2	5.5	0.7	0	0	0	T	0	T	0.4	5.9	23.0

(a) Data based on years of record thru 1960 (third column).

Temperature

Mean annual temperatures vary from about 40° F. at Lake Placid, N.Y., to 54.5° F. at LaGuardia Airport in New York City. The normal annual Sub-regional temperature is about 25° F. during the winter and about 70° F. during the summer. January is the coldest month with average temperatures from 15° F. to 30° F., and July the warmest with temperatures from 70° F. to 75° F. Table C-48 shows mean temperature data for selected stations in the Sub-region.

Humidity

Mean relative humidity generally averages about 75% in January and 70% in July. It ranges from 79% at 1 a.m. to 56% at 1 p.m. at Albany, N.Y., to from 70% to 58% at the same respective times at New York City. The mean dew point temperature in January is about 15° F., and about 60° F. in July. The Sub-region's mean annual dew point temperature is about 35° F., with mean annual readings of 38° F. at Albany and 42° F. at New York City.

Wind

Sub-region C lies in the belt of prevailing westerlies; however, physiographic features orient a large percentage of the winds in a north-south direction, along the axes of the major river valleys. The Hudson-River-Lake Champlain Valley, oriented in a north-south direction, with the Adirondacks and Catskills to the west and the Green Mountains of Vermont to the east, guides the wind along the axis of the valley from a prevailing northerly direction during the winter and from the south in summer. Area 13 is essentially unaffected by topography and winds are generally from the west. Average surface velocities are about 10 m.p.h. in the northwest corner of the Sub-region, about 8 m.p.h. through most of the central portion and about 12 m.p.h. along the coast. Maximum velocities are experienced during hurricanes, with winds of 75 m.p.h. or higher.

Evaporation

Lake evaporation varies from 23 to 31 inches in Sub-region C, with approximately 70% to 80% of the total occurring from May to October. Area 11 has an average annual rate of about 24 inches. The rate ranges from 25 to 30 inches, north to south, in Area 12, and Area 13 averages 31 inches. The Sub-regional average is about 27 inches.

TABLE C-48

TEMPERATURE DATA -SUBREGION C (in degrees Fahrenheit)

Station	Map Code	Years (d) of Record	Elevation ft., m.s.l.	Item	Annual Means	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Monthly Means											
Enosburg Falls, Vt.	1	67	422	Mean Max(a)	54.7	27.9	28.7	39.0	53.6	67.2	75.7	80.3	78.1	70.8	59.6	44.1	30.9
				Mean Min(a)	31.5	4.5	4.7	17.1	30.9	41.9	51.0	55.7	53.1	46.0	35.9	25.9	11.2
				Mean(a)	43.1	16.2	16.7	28.1	42.2	54.6	63.3	68.0	65.6	58.4	47.7	35.0	21.1
Newport, Vt.	2	32	766	Mean Max(a)	52.8	25.7	27.7	36.9	50.6	64.9	74.4	78.7	76.9	68.7	57.4	45.2	28.7
				Mean Min(a)	31.4	4.9	5.4	16.1	30.0	41.7	51.4	55.7	53.4	46.0	35.9	26.2	10.5
				Mean(b)	42.1	15.3	16.8	26.3	40.3	53.3	62.8	67.2	65.3	57.4	46.6	34.3	19.6
Lawrenceville, N.Y.	209	32	480	Mean Max	-	-	-	-	-	-	-	-	-	-	-	-	-
				Mean Min	-	-	-	-	-	-	-	-	-	-	-	-	-
				Mean(b)	44.4	17.2	18.5	28.4	43.0	55.8	65.2	69.9	67.9	60.0	48.7	36.3	21.5
Dannemora, N.Y.	202	58	1,338	Mean Max	-	-	-	-	-	-	-	-	-	-	-	-	-
				Mean Min	-	-	-	-	-	-	-	-	-	-	-	-	-
				Mean(b)	44.0	17.9	19.1	27.9	42.0	55.1	64.5	69.1	67.3	59.7	48.5	35.4	21.6
Canton, N.Y.	200	68	400	Mean Max	-	-	-	-	-	-	-	-	-	-	-	-	-
				Mean Min	-	-	-	-	-	-	-	-	-	-	-	-	-
				Mean(b)	44.4	17.3	18.6	28.7	43.3	55.6	65.1	69.7	67.7	59.6	48.7	36.4	21.9
Lake Placid Club, N.Y.	9	58	1,880	Mean Max(a)	51.1	25.6	26.8	36.6	48.9	62.4	71.4	76.1	79.1	66.8	55.6	40.5	27.9
				Mean Min(a)	28.7	3.8	4.0	13.7	27.0	38.3	47.5	52.1	49.7	42.8	33.4	22.9	9.6
				Mean(b)	40.3	14.9	15.6	24.8	38.6	51.3	60.7	64.9	62.7	55.2	44.8	32.1	18.4
Indian Lake, 25W, N.Y.	10	64	1,660	Mean Max(a)	53.3	28.3	29.3	38.6	50.8	65.2	73.9	78.4	75.9	68.8	57.3	42.5	30.7
				Mean Min(a)	28.1	4.4	3.8	14.0	26.4	36.9	45.9	50.5	48.5	42.4	32.3	23.0	9.2
				Mean(b)	40.5	16.5	16.9	25.4	38.3	50.8	59.9	64.1	62.2	55.0	44.5	32.8	19.6
Speculator, N.Y.	11	15	1,760	Mean Max(a)	54.6	29.5	32.4	38.5	52.9	66.0	75.1	78.6	76.7	69.5	59.4	44.2	31.8
				Mean Min(a)	28.3	5.6	7.1	13.6	27.1	36.5	46.0	49.6	47.6	41.2	31.8	23.6	10.3
				Mean(a)	41.5	17.6	19.8	26.1	40.1	51.3	60.6	64.1	62.2	55.4	45.7	33.9	21.1
Gloversville, N.Y.	203	72	780	Mean(b)	46.2	21.4	22.6	31.2	44.7	56.8	66.1	70.5	68.3	60.3	49.5	37.7	25.0
Poughkeepsie, N.Y.	26	47	103	Mean Max(a)	61.1	35.6	37.1	46.2	60.5	72.3	81.1	85.7	83.5	75.8	64.7	51.5	39.2
				Mean Min(a)	39.5	17.2	17.8	26.3	37.3	47.6	57.0	61.8	60.2	52.6	41.8	32.3	21.6
				Mean(b)	51.0	27.3	28.5	37.3	49.5	60.7	69.6	74.6	72.4	64.6	54.0	42.6	30.5
West Point, N.Y.	28	67	320	Mean Max(a)	60.5	35.2	36.5	46.2	59.7	71.6	80.6	85.3	82.8	75.5	63.5	50.5	38.8
				Mean Min(a)	41.3	19.6	19.6	27.9	38.8	48.9	58.1	63.2	61.7	54.8	44.6	34.8	23.8
				Mean(b)	51.5	28.2	29.3	37.5	49.6	60.6	69.6	74.9	73.0	65.5	54.9	43.2	31.3
White Plains AP, N.Y.	30	12	397	Mean Max(a)	59.9	35.0	39.5	43.9	59.2	68.8	78.8	83.3	81.4	74.0	64.3	51.7	39.4
				Mean Min(a)	42.5	21.7	23.9	28.7	40.1	48.8	58.8	64.6	62.7	54.8	45.3	35.3	25.1
				Mean(a)	51.2	28.4	31.7	36.3	49.7	58.8	68.8	74.0	72.1	64.4	54.8	43.5	32.3
Sussex 1 SE, N.J.	35	62	390	Mean Max(a)	60.8	36.0	37.0	47.3	60.8	72.6	79.9	84.3	81.6	75.9	64.9	51.3	38.4
				Mean Min(a)	38.9	18.5	17.9	26.5	36.7	46.6	55.1	60.4	58.5	52.0	41.0	31.8	21.4
				Mean(b)	50.3	27.7	28.9	37.0	49.1	59.9	68.5	72.9	70.8	63.5	53.2	42.0	30.2
New York C.P., N.Y.	31	46	132	Mean Max(a)	61.9	39.0	40.0	48.1	59.4	70.9	80.0	84.9	82.7	76.7	65.9	53.2	41.9
				Mean Min(a)	46.4	26.1	26.2	33.2	42.6	52.8	62.2	67.6	66.2	60.0	49.8	40.0	29.6
				Mean(b)	54.5	33.2	33.4	40.5	51.4	62.4	71.4	76.8	75.1	68.5	58.3	47.0	35.9
Riverhead Research, N.Y.	33	26	100	Mean Max(a)	61.1	38.3	40.1	46.7	58.4	69.8	78.4	83.1	81.7	75.1	65.3	54.0	42.3
				Mean Min(a)	44.3	25.0	26.1	31.3	40.1	49.2	58.5	64.3	63.8	57.8	48.5	38.6	28.2
				Mean(a)	52.7	31.7	33.1	39.0	49.2	59.5	68.5	73.7	72.8	66.5	56.8	46.3	35.3
Mineola, N.Y.	128	23	128	Mean Max(a)	60.8	38.1	39.8	46.6	58.3	68.9	78.2	83.4	81.7	74.6	64.9	53.2	41.6
				Mean Min(a)	45.7	25.9	26.6	32.3	41.9	51.4	61.0	67.0	65.3	58.5	49.1	39.7	29.2
				Mean(a)	53.2	32.0	33.2	39.5	50.2	60.1	69.6	75.2	73.5	66.6	57.1	46.4	35.4

(a) Data based on period of record thru 1960.
(b) Data based on period 1931-60.
(d) Data based on period of record thru 1965.

HYDROLOGY

Existing Resource

Hydrologic Records. Currently, surface water records at about 120 stations are compiled and published by the U.S. Geological Survey in cooperation with New York State and interested agencies. Area 11 has about 30 stations, Area 12 about 65, and Area 13 has about 25. Additional information is available from the National Weather Service's annual publication, "Daily River Stages." Selected stream gaging stations referred to in this Appendix are located in Figure C-34.

Average Flow. The average flow is 42,160 c.f.s. from the 27,167 square mile drainage area of the Sub-region, which is the equivalent of 21.1 inches of runoff. Runoff on a per square mile basis, ranges from 2.1 c.s.m. in Sub-area 12a to 1.3 c.s.m. in Sub-area 12c, and averages 1.6 c.s.m. for the entire Sub-region. Table C-49 shows estimated average runoff data for Sub-region C.

TABLE C-49
AVERAGE ANNUAL RUNOFF - SUB-REGION C
(Drainage area in square miles, average runoff in c.f.s.

	DRAINAGE AREA	AVERAGE RUNOFF
Sub-area 11a	8,294	12,400
Sub-area 11b	3,606	6,400
AREA 11	11,900	18,800
Sub-area 12a	1,348	2,800
Sub-area 12b	7,212	11,110
Sub-area 12c	4,806	6,500
AREA 12	13,366	20,410
Sub-area 13a 1/	1,397	2,250
Sub-area 13b 2/	504	700
AREA 13	1,901	2,950
SUB-REGION C	27,167	42,160

1/ Includes allowance for sub-surface outflow of 1,300 c.f.s.
2/ Includes allowance for sub-surface outflow of 250 c.f.s.

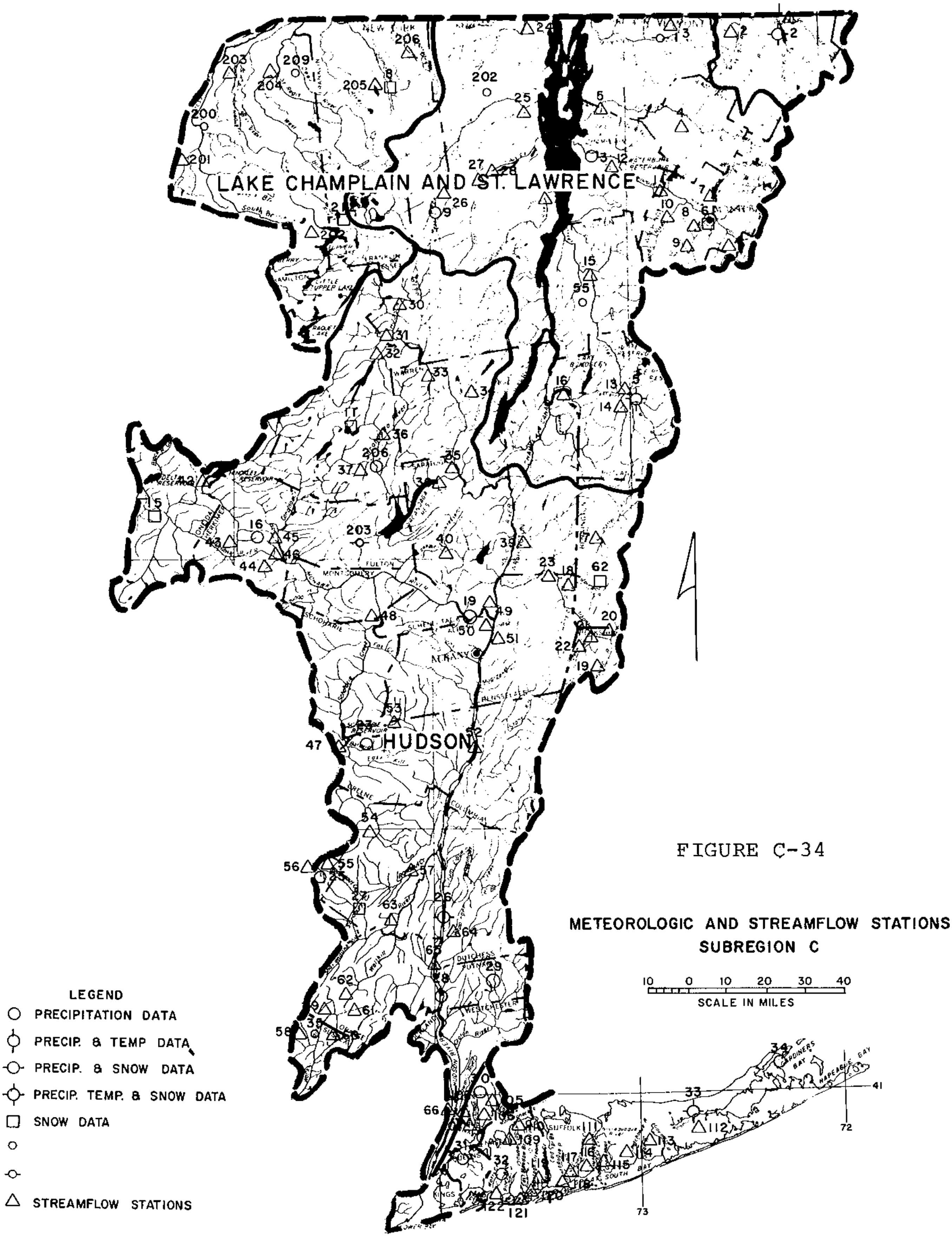


FIGURE C-34

METEOROLOGIC AND STREAMFLOW STATIONS
SUBREGION C

Streamflow Variation. Maximum monthly flows for the tributaries to the St. Lawrence River in Sub-area 11b have occurred most often in April and May, and in Sub-area 11a in March and April. Maximums throughout most of the Hudson River Basin have occurred in April, except in the lower Hudson where maximum monthly flows have occurred most frequently in March. These flows generally fall between four to seven times the average, and on Long Island streams, they are only about twice the average.

Minimum monthly flows occur most frequently in August, September and October throughout most of the Sub-region, and generally range from about 10% or less of average flow. Variation is somewhat less on the upper Hudson where regulatory effects of storage are greatest. Table C-50 shows average maximum and minimum monthly flows for selected steam gaging stations.

Existing Regulation. Sub-region C has nearly 2.6 million acre-feet of existing usable storage capacity, about 2 million of which is located in Area 12. Area 11 contains most of the remainder, used primarily for power with some flood control and recreation. Several large storage reservoirs in the upper Hudson and Mohawk Basins are multiple purpose. Sacandaga Reservoir, for example, is operated for flood control, navigation, municipal supply and power. Most of the storage in the remainder of Area 12 is used for municipal supply. The only existing storage in Area 13 is Kensico Reservoir on the Bronx River which is operated for municipal supply. Table C-5 (p.) summarizes existing major storage by Area.

Significant diversion facilities exist between Areas 12 and 15 (Sub-region D) and between Areas 12 and 13. These facilities are operated in conjunction with New York City reservoirs in the upper Delaware and Hudson River Basins for water supply purposes, principally for Area 13. The yield of these systems is discussed under the Water Availability Analyses Section of this Sub-regional Summary.

Quality and Suitability. The natural quality of surface water is generally good, although a few areas have considerable hardness and excessive amounts of turbidity, color and iron. Dissolved solids concentrations throughout Area 11, in the Hudson River Basin (Area 12) above the Mohawk River, and on Long Island (in Area 13) are relatively low. Elsewhere, concentrations are generally in the range of from 100 p.p.m. to 300 p.p.m. Chemically, surface water is generally of the calcium-magnesium type throughout the Sub-region. Average sediment loads are moderate. Annual sedimentation rates vary from 15 tons per square mile in Area 11, to 93 tons per square mile in Area 13. (See Appendix Q, Erosion and Sedimentation).

Non-industrial and industrial sources of organic waste, the

TABLE C-50

STREAMFLOW DATA (a) - SUBREGION C

Location of Gage	Map Code	D.A., sq.mi.	Years of Record	Average Flow-c.f.s.	Mean Monthly Flow-c.f.s. Maximum	Date	Minimum	Date	Structures Affecting Natural Streamflow
Grass R. at Pyrites, N.Y.	201	335	41	587	2,810	4/47	69.5	8/34	
Raquette R. at Piercefield, N.Y.	202	722	57	1,255	6,094	5/43	54.7	10/48	Lakes and ponds
St. Regis R. at Brasher Center, N.Y.	204	616	55	1,031	4,550	4/12	129	8/34	
Salmon R. at Chasm Falls, N.Y.	205	132	40	221	890	4/60	65.4	8/34	Several reservoirs, diversion
Missisquoi R. nr. Richford, Vt.	3	479	49	902	4,465	4/40	57.5	9/21	
Lamoille R. at Johnson, Vt.	4	310	39	513	2,870	4/33	84.1	10/63	Power plant
Lamoille R. at E. Georgia, Vt.	5	686	36	1,188	5,622	3/36	198	8/34	Power plants
Winooski R. at Montpelier, Vt.	8	397	46	568*	3,442	3/36	60.1	9/21	Several reserviors
Mad River nr. Mooretown, Vt.	10	139	37	243	1,324	3/36	9.19	9/63	
Winooski R. nr. Essex Jct., Vt.	12	1,044	37	1,619*	9,624	3/36	225	8/34	Several reservoirs
Otter Cr. at Center Rutland, Vt.	14	307	37	532	2,376	3/36	85.6	9/47	Several reservoirs
Otter Cr. at Middleburg, Vt.	15	628	49	951	4,538	3/36	126	7/65	Chittenden Res. on East Cr.
Saranac R. at Plattsburgh, N.Y.	25	608	49	812	3,276	4/54	239	11/23	Several reservoirs, diversion
E. Br. Ausable R. at Ausable Forks, N.Y.	27	198	41	300	1,680	4/60	40.5	9/39	Upper & lower Ausable Lakes
Ausable R. nr. Ausable Forks, N.Y.	28	448	55	668	3,290	3/21	96.5	9/21	Taylor Pond and Fern Lake
Bouguet R. at Willsboro, N.Y.	29	275	42	293	1,648	4/33	26.9	9/41	Lincoln Pond
Hoosic R. at Adams, Mass.	19	46.3	34	89.4*	523	4/40	13.3	11/64	Cheshire Res. Div. for Water Supply
Hoosic R. nr. Eagle Bridge, N.Y.	23	510	53	893	4,595	3/36	83.7	10/64	
Hudson R. at Gooley nr. Ind. Lake, N.Y.	31	419	49	822	4,332	4/60	66.0	9/39	Several small reservoirs
Indian R. nr. Indian Lake, N.Y.	32	132	51	285	980	2/32	1.75	11/37	Flow completely regulated by Ind. Lake
Hudson R. at North Cr. N.Y.	33	792	58	1,522	6,899	4/52	161	7/34	Indian Lake
Schroon R. at Riverbank, N.Y.	34	527	58	787	4,401	4/52	54.9	7/65	Schroon Lake at Starbuckville Dam
Hudson R. at Hadley, N.Y.	35	1,664	44	2,816	14,030	4/52	422	1/40	Several reservoirs
Sacandaga R. nr. Hope, N.Y.	37	491	54	1,083	6,140	4/22	52.9	7/34	Several lakes
Sac'daga R. at St'wrts Brdge nr H'dly, N.Y.	38	1,055	58	2,090 *	12,300	4/09	8.4	4/35	Sacandaga Res., Since 3/27/30

TABLE C-50 CONT.

STREAMFLOW DATA (a) - SUBREGION C

Location of Gage	Map Code	D.A., sq.mi.	Years of Record	Average Flow-c.f.s.	Mean Monthly Flow-c.f.s. Maximum	Date	Minimum	Date	Structures Affecting Natural Streamflow
Battenkill at Batten-ville, N.Y.	39	394	43	696	3,718	3/36	66.9	9/64	
Mohawk R. blw. Delta Dam nr. Rome, N.Y.	41	150	44	375	1,201	4/55	85.5	1/61	Delta Res. (1912), diversion
W. Canada Cr. at Hinckley, N.Y.	42	375	40 (thru '59)	984	3,801	5/43	361	9/59	Hinckley Res. (1914)
W. Canada Cr. at Kast Bridge, N.Y.	43	556	45	1,285	6,730	4/12	227	8/34	Hinckley Res. (1914), diversion
Mohawk R. nr. Little Falls, N.Y.	44	1,348	38	2,685	11,990	4/40	642	8/34	Several reservoir & diversions
Schoharie Cr. at Pratts-ville, N.Y.	47	236	62	449	2,804	3/36	6.15	9/64	
Schoharie Cr. at Burtonsville, N.Y.	48	883	26	-	7,580	4/40	4.07	10/64	Schoharie Res., diversion
Mohawk R. at Cohoes, N.Y.	49	3,456	40	5,474	31,870	4/40	671	7/41	Several reservoirs, diversions
Hudson R. at Green Is., N.Y.	50	8,090	19	12,710	51,610	4/60	2,875	9/64	Several reservoirs, diversions
Kinderhook Cr. at Rossman, N.Y.	52	329	41	446	2,594	3/36	8.65	9/64	
Esopus Cr. at Cold-brook, N.Y.	54	192	52	-	2,812	3/36	23.4	10/64	Water div. fr. Schoharie Cr. into Esopus Cr.
Rondout Cr. at Rosen-dale, N.Y.	57	386	39 (thru '50)	777 *	3,821	3/36	16.8	9/64	Diversion, Rondout Res.
Walkill R. at Pellets Is. Mt., N.Y.	62	385	45	557	3,263	3/36	12.4	9/64	
Wallkill R. at Gardiner, N.Y.	63	711	41	1,029	5,947	3/36	18.9	9/64	
Wappinger Cr. nr. Wappinger Falls, N.Y.	64	182	37	236	1,195	3/36	4.29	9/64	
Peconic R. at River-head, N.Y.	112	75	23	35.5	84.82	4/53	16.0	9/65	
Carmens R. at Yaphank, N.Y.	113	71	23	24.2	38.56	4/56	15.2	9/65	
Connetquot R. nr. Oakdale, N.Y.	115	24	22	39.4	67.32	11/55	22.5	9/65	
Sampawams Cr. at Baby-lon, N.Y.	117	23	21	9.79	22.03	4/58	3.98	9/65	
E. Meadow Brk. at Freeport, N.Y.	121	31	26	17.5	34.73	4/53	0.42	9/65	

(a) Based on observed flows except for data with asterisks (*) which have been adjusted for some effects of regulation. Data utilized thru water year 1965 except as otherwise noted.

Note: Stations are not necessarily listed in the usual downstream order. Refer to map code number requences.

most significant degraders of water in the Sub-region, contributed 19 million population equivalents (PE) of biodegradables, as measured by biochemical oxygen demand (BOD), to the Sub-region's waters in 1960. Industrial discharges contribute about 65% of the load. Combined sewer outflows and inorganic pollutants generally follow the areal pattern of organic pollution in degree of severity. (See Appendix L, Water Quality and Pollution.)

Water quality problem areas include the lower Hudson River and estuary in the New York City vicinity, the Hudson River below Albany, the middle and upper portions of the Mohawk River and several tributaries to Lake Champlain.

Floods. Flooding in the St. Lawrence River Basin is mostly local and damages are relatively minor. Lakes, swamps and man-made reservoirs aid in reducing flood peaks. Minor damages have occurred on the Oswegatchie and Salmon Rivers during spring run-off, usually as a result of ice james. The most serious flooding in the Lake Champlain Basin is on the Great Chazy River at Champlain, N.Y., and on the Metawee River, where agricultural inundation is experienced. The flooding is generally limited to a few isolated locations.

Serious floods can occur in the Hudson Basin at almost any time of the year. Spring floods occur nearly every few years as a result of heavy rains, snowmelt, or a combination of both, often resulting in severe flood conditions in portions of the Basin. Ice jams add to the high river stages, increasing the spring flood hazard. Transcontinental and tropical storms occasionally affect the entire Basin, but damages are usually confined to separate locations. Local flash flooding may occur during the summer along tributaries. Flooding in Area 13 is mostly caused by high tides associated with tropical storms and by localized cloudbursts.

Table C-51 lists recorded flood data for selected stations in the Sub-region. Peak frequency information is included in Table C-3 (p. C-17).

Low Flow. Some of the significant low flow periods in the Sub-region in this century occurred in 1914, 1930, 1931, 1934, 1941, 1957, and from 1961 through 1966. The 1960's drought severely affected the lower portion of the Sub-region. For example, annual flows on Kinderhook Creek at Rossman, N.Y., were about 56% of average during the period, 1963-1966, and during the same period, flows on the Walkill River at Pellets Island Mountain were about 55% of average.

Surface water flow on Long Island was well below normal during the latter years of the 1960's drought, in almost direct proportion to drawdown in ground water levels. Tributaries to the St. Lawrence

TABLE C-51

FLOOD DATA - SUBREGION C

Location	Map Code	Latest Data (Date)	Flood No. 1 Date	Flood No. 1 Peak Q. c.f.s.	Flood No. 1 Stage, ft.	Flood No. 1 $Q/(D.A.)^{.5}$	Flood No. 2 Date	Flood No. 2 Peak Q. c.f.s.	Flood No. 2 Stage, ft.	Flood No. 2 $Q/(D.A.)^{.5}$	Flood No. 3 Date	Flood No. 3 Peak Q. c.f.s.	Flood No. 3 Stage, ft.	Flood No. 3 $Q/(D.A.)^{.5}$
Grass R. at Pyrites, N.Y.	201	9/65	11/18/27	8,300	13.00	450	4/ 6/37	7,390	12.00	400	3/28/50	6,950	11.80	380
Raquette R. at Piercefield, N.Y.	202	9/65	5/16/43	8,240	12.10	310	4/17/22	7,580	11.80	280	4/21/55	7,240	11.60	270
St. Regis R. at Brasher Cts., N.Y.	204	9/65	4/ 6/37	16,800	12.90	680	4/ 7/11	16,240	-	650	4/ 6/12	15,750	9.00	630
Salmon R. at Chasm Falls, N.Y.	205	9/65	4/25/26	2,870	5.00	250	4/ 8/28	2,820	5.00	250	4/12/47	2,620	4.80	230
Missiquoi R. nr. Richford, Vt.	3	9/65	5/ 4/40	17,200	15.15	790	3/19/36	16,000	14.70	730	6/21/36	14,300	13.88	650
Lamoille R. at Johnson, Vt.	4	9/65	3/18/36	13,000	16.48	740	4/ 8/12	12,200	16.40	690	5/ 3/40	11,400	15.28	650
Lamoille R. at E. Georgia, Vt.	5	9/65	3/19/36	23,200	12.52	890	5/ 3/40	22,300	12.25	850	9/22/38	20,200	11.76	770
Winooski R. at Montpelier, Vt.	8	9/65	4/ 7/12	17,200	17.31	860	3/18/36	15,600	16.57	780	1/10/35	13,500	-	680
Mad R. nr. Mooretown, Vt.	10	9/65	9/22/38	18,400	16.34	1,560	6/ 3/47	10,100	11.51	860	12/31/48	8,780	10.75	750
Winooski R. nr. Essex Jct., Vt.	12	9/65	11/ 4/27	113,000	50.40	3,500	3/19/36	45,300	23.54	1,400	4/19/33	34,600	18.60	1,070
East Cr. at Rutland, Vt.	13	9/65	6/ 3/47	36,500	20.30	5,100	6/25/45	3,450	7.10	480	11/26/50	2,190	5.32	310
Otter Cr. at Middlebury, Vt.	15	9/65	11/ 4/27	13,600	13.30	340	3/21/36	11,000	10.30	440	3/30/13	9,950	-	400
Saranac R. at Plattsburgh, N.Y.	25	9/65	4/ 8/28	11,500	-	470	6/ 3/47	9,250	9.57	380	4/ 4/63	7,680	9.00	310
E. Br. Ausable R. at Ausable Forks, N.Y.	27	9/65	9/22/38	20,100	12.91	1,430	12/31/48	16,500	11.60	1,170	12/21/57	11,100	9.60	790
Ausable R. nr. Ausable Forks, N.Y.	28	9/65	9/22/38	24,200	11.65	1,140	12/31/48	23,200	1.39	1,100	10/ 1/24	21,200	11.15	1,000
Bouquet R. at Willsboro, N.Y.	29	9/65	10/ 1/24	11,800	10.85	720	3/19/36	8,310	9.13	500	12/31/48	7,790	8.86	470
Hoosic R. at Adams, Mass.	19	9/65	9/21/38	5,080	9.25	750	3/18/36	3,670	6.33	540	12/31/48	3,100	7.81	460
Hoosic R. nr. Eagle Bridge, N.Y.	23	9/65	12/31/48	55,400	21.15	2,470	11/ 4/27	41,500	18.80	1,840	9/22/38	35,300	17.78	1,560
Hudson R. at Gooley nr. Ind. Lake, N.Y.	31	9/65	1/ 1/49	15,000	5.99	730	4/12/22	13,900	10.00	680	9/28/42	13,600	9.89	660
Indian R. nr. Ind. Lake, N.Y.	32	9/65	5/28/13	3,460	7.80	300	5/13/43	2,880	7.05	250	4/21/52	2,440	6.42	210
Hudson R. at North Creek, N.Y.	33	9/65	12/31/48	28,900	12.14	1,030	3/27/13	28,400	12.00	1,010	6/ 3/47	23,600	11.37	840
Schroon R. at Riverbank, N.Y.	34	9/65	3/21/36	12,100	12.18	520	5/28/13	10,400	10.70	450	4/13/22	9,740	10.23	420
Hudson R. at Hadley, N.Y.	35	9/65	1/ 1/49	42,700	21.21	1,050	3/18/36	41,200	19.59	1,010	4/12/22	33,100	19.71	810
Sacondaga R. nr. Hope, N.Y.	37	9/65	3/27/13	32,000	11.00	1,570	12/31/48	31,400	10.55	1,540	3/18/36	23,900	-	1,170
Sacandaga R. at. Stewarts Brd'ge nr. Hadley, N.Y.	38	9/65	3/28/13	35,500	12.36	1,090	4/13/22	23,100	10.70	710	4/26/26	22,500	10.60	690
Batten Kill at Battenville, N.Y.	39	9/65	11/ 4/27	21,300	17.70	1,070	12/31/48	18,000	15.88	910	9/22/38	16,000	14.82	810
Mohawk R. blw. Delta Dam nr. Rome, N.Y.	41	9/65	10/ 2/45	8,560	11.18	700	5/22/47	6,350	9.86	520	7/ 9/35	4,060	8.10	330
W. Canada Cr. at Hinckley, N.Y.	42	9/65	10/ 2/45	17,100	12.94	880	6/ 3/47	13,200	10.10	680	3/28/48	12,400	9.82	640
W. Canada Cr. at Kast Bridge, N.Y.	43	9/65	3/26/13	23,300	-	990	10/ 2/45	20,500	8.08	870	4/23/60	16,700	7.43	710
Mohawk R. nr. Little Falls, N.Y.	44	9/65	3/ 5/64	27,200	18.33	740	10/ 3/45	25,300	17.80	690	3/18/36	23,200	17.24	630
Schoharie Ct. at Prattsville, N.Y.	47	9/65	10/16/55	55,200	19.14	3,590	9/12/60	49,900	18.35	3,240	11/25/50	49,500	15.50	2,920
Schoharie Cr. at Burtonsville, N.Y.	48	9/65	10/16/55	76,500	12.39	2,570	3/31/51	37,900	8.00	1,270	4/ 4/60	30,500	7.25	1,030
Mohawk R. at Cahoes, N.Y.	49	9/65	3/ 6/46	143,000	23.15	2,430	3/19/36	130,000	22.57	2,210	9/22/38	102,000	20.61	1,720
Hudson R. at Green Is., N.Y.	50	9/65	12/31/48	181,000	27.05	2,010	3/ 6/64	141,000	24.82	1,560	4/ 5/60	134,000	24.41	1,480
Kinderhook Cr. at Rossman, N.Y.	52	9/65	12/31/48	29,800	19.80	1,640	9/22/38	27,800	18.40	1,530	7/23/45	15,800	11.38	870
Esopus Cr. at Coldbrook, N.Y.	54	9/65	3/30/51	59,600	20.70	4,310	8/24/33	55,000	-	3,970	10/15/55	54,000	20.00	3,900
Randout Cr. at Rosendale, N.Y.	57	9/65	10/16/55	35,800	26.80	1,820	8/19/55	30,900	23.93	1,570	8/27/28	27,300	21.90	1,390
Walkill R. at Pellets Is. Mt., N.Y.	62	9/65	3/14/36	12,400	25.00	630	8/21/55	10,100	21.76	510	10/17/55	9,580	21.22	490
Walkill R. at Gardiner, N.Y.	63	9/65	10/16/55	30,800	19.81	1,160	8/19/55	30,600	19.77	1,150	6/ 1/52	21,200	14.88	800
Wappinger Cr. nr. Wappinger Falls, N.Y.	64	9/65	8/19/55	18,600	19.60	1,380	9/22/38	15,900	18.02	1,180	10/16/55	8,170	12.47	610
Peconic R. at Riverhead, N.Y.	112	9/65	4/14/53	140	0.97	20	4/11/57	128	0.93	10	4/16/58	125	0.92	10
Carmens R. at Yaphank, N.Y.	113	9/65	9/11/54	83.2	1.25	10	10/16/55	81.6	1.18	10	8/ 7/46	76.3	1.19	10
Conetquot R. nr. Oakdale, N.Y.	115	9/65	10/16/55	263	-	50	8/ 7/46	117	-	20	9/15/44	101	-	20
Sampowams Cr. at Babylon, N.Y.	117	9/65	9/12/60	136	2.11	30	7/20/61	108	1.79	20	10/16/55	98	1.67	20
E. Meadow Brook at Freeport, N.Y.	121	9/65	9/12/60	835	4.38	150	7/31/61	465	2.87	80	11/10/62	462	2.82	80

Note: Stations are not necessarily listed in the usual downstream order. Refer to map code number sequences.

River were least affected by that drought. Although some record low flows were established in 1965, drought conditions were neither as prolonged nor as severe as in other parts of the Sub-region. Lake Champlain tributaries seem to have been more severely affected, with a record low of about 30% of average on the Poultney River for Water Year 1965.

Ground Water. Ground water in the northern part of the Sub-region comes mostly from bedrock and glacial drift. Glacial deposits account for the greater portion of existing yields with many wells producing several hundred gallons per minute, and some local areas yielding a few thousand gallons per minute. The most productive supply in the Sub-region is on Long Island, from stratified glacial drift and underlying sand and gravel. Ground water on Long Island occurs under both water table and artesian conditions.

Ground water quality varies considerably. In the Lake Champlain and St. Lawrence River Basins, where dolomite is the most productive bedrock unit, the deeper wells are sometimes contaminated by sulfides. Water quality in the Hudson Basin generally meets drinking water standards, although some of the ground water is high in iron and manganese. Long Island ground water is generally good, but is subject to local saline water intrusion.

Estuaries and Coastal Areas. The principal features composing the coastal and estuarine areas in Sub-region C are Long Island Sound, the Hudson River estuary, and the nearly-continuous bank of estuaries behind barrier beaches along the South Shore of Long Island. Tidal ranges average about 3 feet at the tip of Long Island and gradually increase westward along both shores, reaching about 7 feet at the head of the Sound and in the New York Bight. Tide ranges are about 4.5 feet at the head of tide at Albany, N.Y.

Water Availability Analyses

Evapotranspiration. The normal annual evapotranspiration in the Sub-region ranges from about 15 inches or less in the northern portion to from 20 to 25 inches in the south. Normal annual July evapotranspiration is between 5 and 5.5 inches and reservoir surface evaperation for July is about 4.5 inches. Assuming no change in ground water storage, and subtracting the average annual runoff of approximately 20 inches from the average annual precipitation of 41 inches, the average annual rate of evapotranspiration would be roughly 21 inches. Average net losses from reservoir surfaces, or evaporation minus evapotranspiration from the area a reservoir replaces, would be approximately 6 to 7 inches annually. This value is subject to wide seasonal and geographic variation. However, there may be gains on a seasonal or other short term basis due to the interception of precipitation directly onto the lake surface instead of seeping first into the ground.

Streamflow Simulation. The method used to estimate missing monthly streamflows through 1967 is described in Chapter 3. Table C-52 lists the key streamflow stations used in this analysis. The stations are grouped according to the numeral shown in the left hand column of the Table. These groups were used for correlation analysis in the generation of synthetic streamflow traces, as well as for the estimation of missing monthly flows. All historic records were extended to a period of 81 years. Ten 100-year periods were generated at each station. The stations cover a total drainage area of 13,553 square miles. Schematic diagrams showing station locations and incremental or local drainage areas are shown on Figure C-35. A summary of the maximum and minimum occurrences for the recorded and reconstituted flows and for all 10 periods of generated flows are given in Table C-53.

Yield-Storage Relationships. The yield-storage relationships were derived by the methods described in Chapter 3. Table C-54 summarizes results in Sub-region C, giving a comparison between historic and synthetic storage requirements at selected demand rates. At demand rates of 40% and 60% of the average annual flow, the storage requirement for the historic record is generally greater than for the generated record, except for the streams directly tributary to the St. Lawrence River in the western part of Area 11. At a demand rate of 80%, the storage requirement for the historic record is generally less in Area 11 and in the upper reaches of the Hudson River, and higher in the Mohawk and lower Hudson River Basins where the effects of the recent drought were most severe. Figure C-36 shows the relationship between yield and storage for the Hudson River at Hadley, N.Y., as a typical example of the graphic format adopted for use.

Minimum Flow. For purposes of plan formulation, Sub-region C was divided into three Areas, and further into seven Sub-areas. The existing minimum flow for each sub-area was derived by computing the monthly flow value from the historic record for a shortage index of .01. An adjustment, based on the ratio of the mean seven-day flow during the dry season to the mean minimum monthly flow, was applied to obtain the seven-day low flow for each Sub-area. (See Chapter 3, for discussion of this methodology.) Where a gaging station did not correspond to a Sub-area outlet, nearby gaging stations were used to estimate the flow for the Sub-area concerned. Table C-55 lists the minimum flows derived for the Sub-areas in Sub-region C for a shortage index of 0.01. As described in Chapter 3, adopted seven-day minimum flows are considered to have recurrence intervals of approximately 50 years.

TABLE C-52
KEY STREAMFLOW STATIONS
SUB-REGION C

Analysis Group	NAR Number	Station	Drainage Area (Sq. Mi.)	Approx. Yrs. of Observed Record
I	301	Hudson R. at Gooley nr Indian L., N.Y.	419	51
I	352	Hudson R. at North Creek, N. Y.	792	59
I	353	Hudson R. at Hadley, N. Y.	1,664	46
I	304	Sacandaga R. nr Hope, N. Y.	491	56
I	355	Sacandaga R. at Stewarts Br. nr Hadley, N. Y.	1,055	60
IV	306	Batten Kill at Battenville, N. Y.	394	45
IV	307	Hoosic R. nr Eagle Bridge, N. Y.	510	57
ALL	378	Hudson R. at Mechanicville, N. Y.	4,500	79
II	359	W. Canada Cr. at Kast Bridge, N. Y.	556	47
II	360	Mohawk R. nr Little Falls, N. Y.	1,348	40
II,IV,V	311	Schoharie Cr. at Prattsville, N. Y.	236	65
II	362	Schoharie Cr. at Burtonsville, N.Y.	883	28
I,II	363	Mohawk R. at Cohoes, N. Y.	3,456	49
IV,V	314	Kinderhook Cr. at Rossman, N. Y.	329	43
V	315	Walkill River at Pellets Is. Mtn., N. Y.	385	47
III	316	Grass R. at Pyrites, N.Y.	335	43
III	317	Raquette R. at Piercefield, N. Y.	722	59
III	318	St. Regis R. at Brasher Center, N. Y.	616	57
III	319	Saranac R. at Plattsburgh, N. Y.	608	51
III	320	Ausable R. nr Ausable Forks, N. Y.	448	57

TABLE C-52 CONT.
KEY STREAMFLOW STATIONS
SUB-REGION C

Analysis Group	NAR Number	Station	Drainage Area (Sq. Mi.)	Approx. Yrs. of Observed Record
III	321	Bouquet R. at Willsboro, N. Y.	275	44
I,II,III,IV	322	Otter Cr. at Middlebury, Vt.	628	50
IV	373	Winouski R. at Montpelier, Vt.	397	48
IV	324	Lamoille R. at E. Georgia, Vt.	686	38
VI	325	E. Meadow Brook at Freeport, N. Y.	31	30
VI	326	Sampawanms Cr. at Babylon, N. Y.	23	23
VI	327	Connetquot R. nr Oakdale, N. Y.	24	24
VI	328	Carmans R. at Yaphank, N. Y.	71	25
VI	329	Peconic R. at Riverhead, N. Y.	75	25

FIGURE C-35

SCHEMATIC DIAGRAM
KEY STREAMFLOW STATIONS
SUB-REGION C

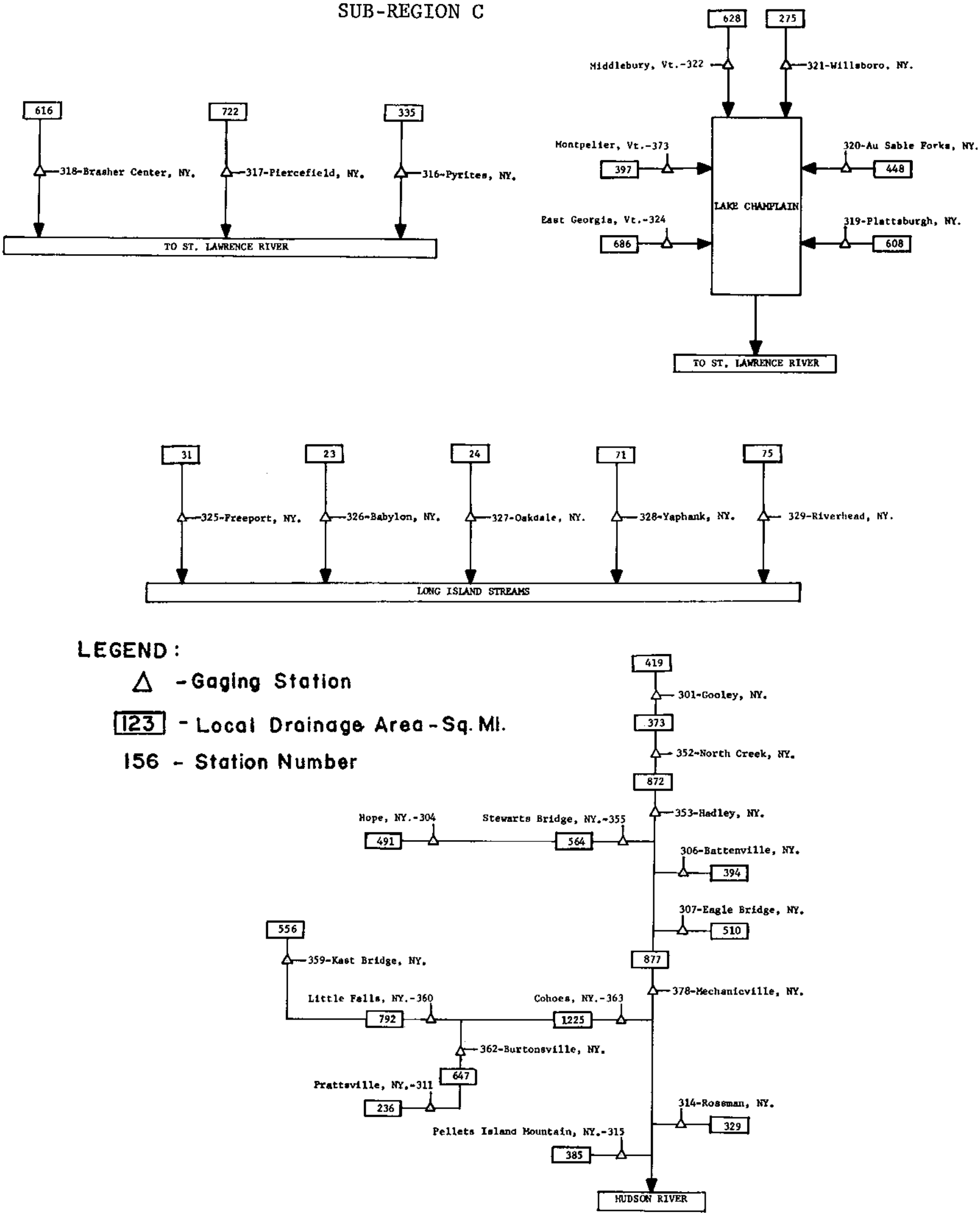


TABLE C-53
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION C
(Cubic feet per second)

Sta.			1 Month		6 Months		54 Months	
			Max.	Min.	Max.	Min.	Max.	Min.
301		Hist.	4,332	55	11,750	966	54,791	32,170
	Gen.	High	7,665	54	15,721	1,238	66,843	36,176
		Low	4,816	17	12,146	782	56,987	26,932
352		Hist.	7,857	102	21,230	1,728	102,457	58,756
	Gen.	High	14,706	91	29,307	2,333	124,114	66,651
		Low	8,099	43	21,552	1,366	104,975	49,480
353		Hist.	14,742	263	40,498	3,214	193,533	104,766
	Gen.	High	31,947	278	57,999	4,242	234,943	125,188
		Low	15,647	119	37,954	2,799	193,028	93,658
304		Hist.	6,143	52	17,254	819	74,749	40,443
	Gen.	High	10,195	58	21,222	1,313	89,214	45,363
		Low	5,775	28	15,477	699	76,421	35,193
355		Hist.	12,319	15	30,205	1,170	140,812	76,739
	Gen.	High	16,867	40	39,357	2,125	166,541	88,228
		Low	11,405	9	30,512	1,109	146,833	65,280
306		Hist.	3,718	166	9,802	623	49,149	25,346
	Gen.	High	4,305	776	14,625	1,041	57,956	29,496
		Low	3,101	37	9,984	837	47,076	25,230

TABLE C-53 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION C

Sta.			1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
316	Hist.		2,810	60	9,085	979	39,580	24,976
	Gen.	High	3,403	72	10,233	1,034	46,722	24,412
		Low	3,001	44	8,451	750	39,731	~~7~~0,481 2
317	Hist.		6,094	54	17,722	1,658	91,057	51,188
	Gen.	High	9,087	119	22,619	1,981	99,978	53,460
		Low	5,827	19	16,694	1,356	86,846	47,323
318	Hist.		4,550	129	15,183	1,685	70,768	40,801
	Gen.	High	5,427	132	16,786	1,932	78,057	42,849
		Low	4,697	66	14,409	1,314	67,991	36,052
319	Hist.		3,276	239	12,628	1,848	56,777	35,078
	Gen.	High	3,664	241	12,386	1,935	62,244	33,668
		Low	3,240	171	10,042	1,541	53,704	31,216
320	Hist.		3,436	43	9,903	999	44,992	26,091
	Gen.	High	5,932	89	13,037	1,165	55,376	25,881
		Low	3,685	51	10,456	871	46,026	22,526
321	Hist.		1,648	26	4,411	339	20,575	11,211
	Gen.	High	2,242	30	6,444	394	25,232	11,484
		Low	1,761	21	4,742	293	21,078	9,556

TABLE C-53 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION C

Sta.			1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
360		Hist.	13,826	222	36,222	3,001	191,416	108,129
	Gen.	High	23,594	222	47,385	3,844	235,544	122,810
		Low	12,872	85	39,417	2,938	183,353	98,007
362		Hist.	9,084	14	19,499	415	91,453	42,169
	Gen.	High	17,338	30	34,160	772	111,595	52,497
		Low	8,761	5	21,383	562	95,430	41,022
363		Hist.	35,140	416	76,603	4,226	422,502	217,416
	Gen.	High	43,409	365	111,041	7,400	491,661	262,267
		Low	28,530	105	92,942	5,099	412,801	211,813
314		Hist.	2,646	7	7,485	141	37,334	12,050
	Gen.	High	3,307	17	9,863	372	38,346	18,662
		Low	2,299	0	6,971	163	32,837	14,482

TABLE C-54

STORAGE REQUIREMENT IN AF/SQ. MI. FOR INDICATED PERCENTAGES OF AVERAGE FLOW

SUBREGION C.

Station	D.A. SQ.MI.	AVERAGE FLOW.CFS.	S.I. = 0.0 HISTORIC 20%	40%	60%	80%	S.I. = .01 H 20%	S 20%	H 40%	S 40%	H 60%	S 60%	H 80%	S 80%	S.I. = 0.10 SYNTHETIC 20%	40%	60%	80%	Historic Rec. (Actual & Estimated) yrs.
Grass R. at Pyrites,N.Y.	335	596	17	95	245	480	10	-	75	75	210	225	420	700	-	35	140	430	81
Raquette R. at Piescefield,N.Y.	722	1,300	30	130	305	660	16	16	96	100	240	245	520	700	-	48	150	420	81
St. Regis R. at Brasher Ctr.,N.Y.	616	1,034	-	90	245	640	-	-	70	76	195	220	510	680	-	20	130	400	81
Saranac R. at Pittsburgh,N.Y.	608	816	-	22	160	330	-	-	10	10	120	94	300	350	-	-	50	210	81
Ausable R. nr. Ausable Forks,N.Y.	448	676	25	100	250	570	12	-	74	72	200	220	480	660	-	37	145	420	81
Bouquet R. at Willsboro,N.Y.	275	302	21	115	260	575	17	-	90	82	225	215	480	600	-	46	145	390	81
Otter Cr. at Middlebury,Vt.	628	980	-	100	390	810	-	-	70	62	320	220	740	500	-	18	125	310	81
Winooski R. at Montpelier,Vt.	397	584	-	120	280	750	-	-	85	84	230	210	650	680	-	53	150	370	81
Lamoille R. at E. Georgia,Vt.	686	1,256	-	110	290	580	-	-	76	65	225	210	480	540	-	23	130	300	81
Hudson R. at Gooley nr. Ind. Lake,N.Y.	419	840	-	215	430	800	-	-	175	140	370	325	660	970	-	80	225	540	81
Hudson R. at North Creek,N.Y.,Lcl.	373	710	-	200	410	990	-	-	155	135	350	320	800	1,000	-	80	225	570	81
Hudson R. at Hadley, N.Y.,Lcl.	872	1,340	30	175	385	930	21	21	145	98	320	270	870	690	-	65	195	450	81
Sacandaga R. nr. Hope,N.Y.	491	1,113	-	220	510	1,170	-	-	195	180	430	400	1,050	1,200	-	120	290	740	81
Sac. R. at Stewart's Br. nr Hadley,NY,Lcl	564	1,008	98	310	520	900	76	73	250	200	440	360	760	1,040	48	130	270	620	81
Batten Kill at Battenville,NY	394	712	-	170	390	900	-	-	135	105	290	220	750	800	-	58	150	450	81
Hoosic R. nr. Eagle Br.,N.Y.	510	908	-	210	450	1,100	-	-	160	120	380	245	1,000	760	-	70	165	420	81
Hudson R. at Mechanicville, N.Y.	4,500	7,336	59	180	340	920	36	32	145	120	310	280	800	620	12	78	180	430	80
W. Canada Cr. at Kast Br.,N.Y.	556	1,376	43	175	410	1,050	15	15	125	130	325	310	850	900	-	72	200	540	81
Mohawk R. nr. Little Falls,N.Y.	792	1,448	58	210	450	920	44	42	170	150	330	330	730	700	23	100	245	480	81
Schaharie Cr. at Prattsville,N.Y.	236	452	120	270	630	1,350	94	85	225	230	500	550	1,170	1,190	50	170	390	860	81
Schaharie Cr. at Burtonsville, N.Y.,Lcl.	647	860	78	235	500	1,000	65	65	200	160	400	335	840	820	40	110	245	580	81
Mohawk R. at Cohoes, N.Y.,Lcl.	1,225	1,992	90	225	430	1,250	70	65	180	160	370	350	840	800	46	105	230	540	81
Mohawk R. at Cohoes, N.Y.	3,456	6,114	50	180	360	750	36	31	160	135	320	320	620	750	13	92	210	470	81
Kinderhook Cr. at Rossman,N.Y.	329	465	-	220	590	1,700	-	-	190	150	530	285	1,550	940	-	105	215	560	81
Walkill R. at Pellets Is. Mtn.,N.Y.	385	577	72	220	640	1,680	58	70	175	170	630	380	1,650	950	43	125	240	640	81
E. Meadowbrook at Freeport,N.Y.	31	19	34	135	315	460	27	21	120	67	280	185	440	440	-	21	76	220	81
Sampawams Cr. at Babylon,N.Y.	23	10	-	25	90	150	-	-	-	-	76	58	95	185	-	-	24	105	81
Conetquot Cr. nr. Oakdale,N.Y.	24	40	-	-	35	270	-	-	-	-	-	-	170	150	-	-	-	10	81
Carmans R. at Yaphank,N.Y.	71	24	-	-	72	100	-	-	-	-	21	26	67	110	-	-	-	37	81

H = Historic Record
S = Synthetic Record

S.I. = Shortage Index
Lcl = Local area above station

FIGURE C-36. SAMPLE YIELD-STORAGE CURVES - SUB-REGION C

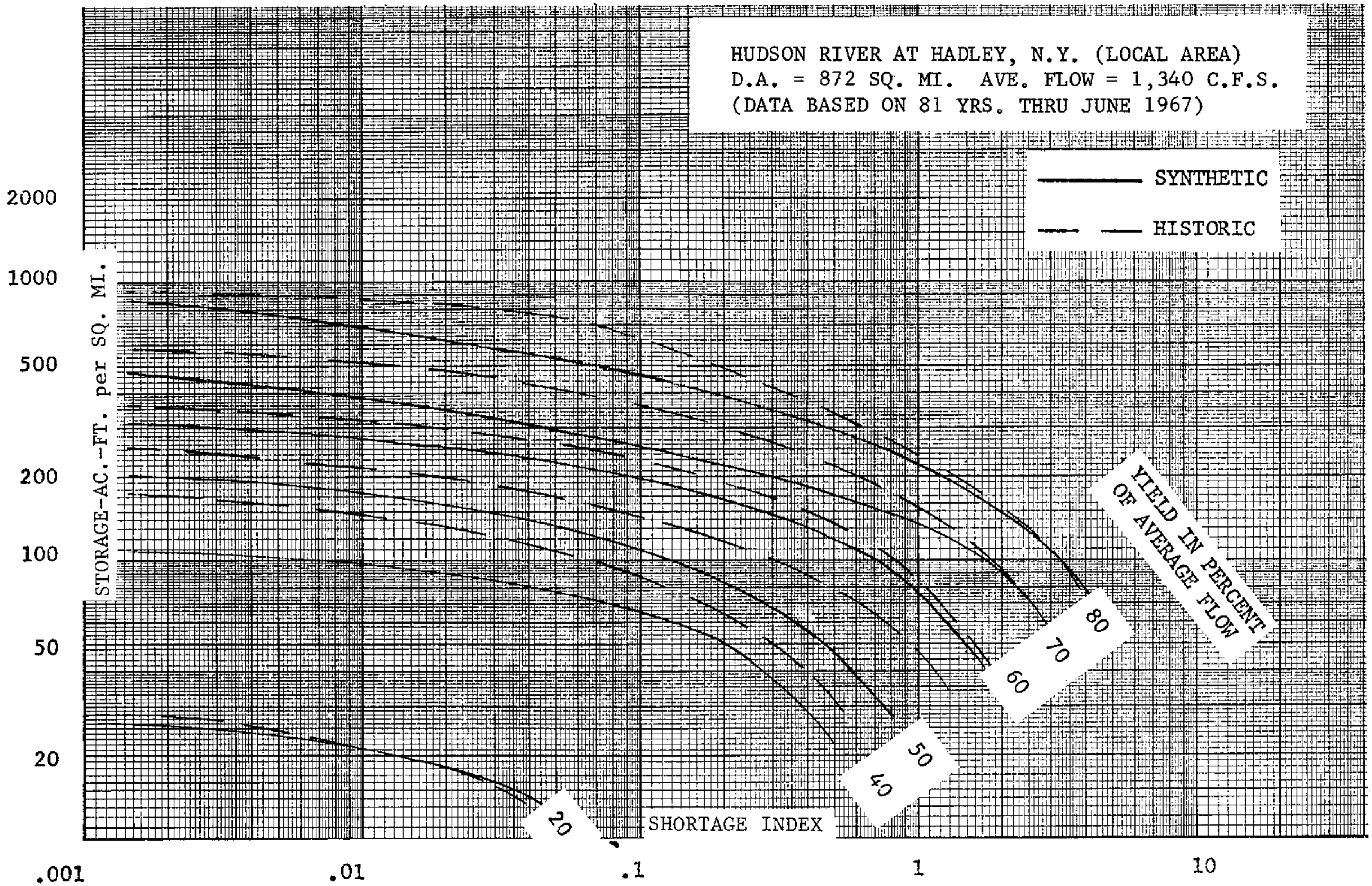


TABLE C-55
EXISTING MINIMUM STREAMFLOW - SUB-REGION C
(Cubic feet per-second)

	MONTHLY	7-DAY
Sub-area 11a	2,910	1,735
Sub-area 11b	1,270	755
AREA 11	4,180	2,490
Sub-area 12a	1,025	550
Sub-area 12b	2,440	1,380
Sub-area 12c	245	125
AREA 12 1/	3,710	2,055
Sub-area 13a	265	240
Sub-area 13b	75	50
AREA 13	340	290
SUB-REGION C	8,230	4,835

1/ Does not include 840, m.g.d. developed for export.

The determination of the yield of major water supply reservoirs was made separately, using a shortage index of 0.01 and yield-storage relationships derived from the synthetically generated streamflow traces. On this basis, it was estimated that the three New York City reservoirs in Area 15 -- Pepacton, Cannonsville and Neversink -- would yield 540 m.g.d. for diversion to Area 12. This assumes that it would be necessary to maintain a flow of 1,750 c.f.s. in the Delaware River at Montague, N.J., in accordance with the 1954 Supreme Court decree.

Analysis of the existing New York City water supply storage within Area 12 using the above yield-storage criteria (and assuming drawdown of 75% of the total reservoir storage) results in a yield of approximately 840 m.g.d. This includes Schoharie, Ashokan and Rondout Reservoirs, as well as the Croton System.

The above minimum flow and reservoir yield data have been used to determine the developable resource covered in Appendix E and in connection with the NAR Supply Model analyses.

SUB-REGION D

Sub-region D includes northern New Jersey streams, the Delaware River Basin, and streams along the New Jersey coast. The Sub-region's topography varies from the mountainous terrain of Delaware Basin headwaters to the flatlands of the coastal area. There are about 17,534 square miles in the Sub-region. Areas and Sub-areas are shown in Figure C-1.

The average annual precipitation is approximately 45 inches, with a range of from 40 to 60 inches. The greater rainfall occurs in the mountainous areas, with the higher values coming during July and August. Average snowfall ranges from 17 inches in southern New Jersey to more than 75 inches at Roxbury, N.Y. Late summer and fall storms of tropical origin often produce a significant portion of the total precipitation. Because of the accumulated precipitation deficiency, drought conditions in the early-1960s were more extreme in Sub-region D than in most of the remainder of the NAR. Some areas experienced a rainfall deficiency of about 12 inches per year for the five-year period through 1966.

Average annual temperatures are 45° F. in the northern part of the Sub-region, and 55° F. in the south. Wind speeds average 10 m.p.h., and winds are generally from the northwest during the winter, and west-to-southwest in the summer. Average annual lake evaporation ranges from 28 to 38 inches, north to south.

Geographically, runoff in the Sub-region is relatively evenly distributed, with an annual average of about 21.5 inches. The highest runoff occurs during the early spring and the lowest during late summer. Hurricane-type storms cause the highest degree of flooding. The drought of the early-1960s was the most severe experienced in Sub-region D, with runoff about two-thirds of average in many locations for periods of up to five years. The observed minimum seven-day flow is equivalent to about 0.27 c.s.m. (Shortage Index 0.01).

Surface waters are mostly soft to moderately hard and, except for the waters of the upper Schuylkill River, are generally low in dissolved solids concentrations. Coastal Plain aquifers are highly productive, yielding 500 g.p.m. or more in many areas.

The main coastal and estuarine features are Delaware Bay and the long, sandy barrier beaches along the New Jersey shore.

CLIMATE AND METEOROLOGY

Meteorologic Records

The number of meteorologic data stations is fairly ample, providing data which give an adequate description of Sub-region D's climate. A number of available records are of long duration and there is a good geographic distribution. Figure C-37 shows the location of some of the available data stations referred to in this section. The principal source of data is the National Weather Service, in cooperation with several states.

Precipitation

Sub-region D's average annual precipitation is about 45 inches, ranging from about 40 inches in the more southern locations to about 60 inches in the mountainous headwater areas. The highest average monthly precipitation occurs in July and August, and the lowest during February and October. Variations in monthly temperature are greatest in July, August and September. Table C-56 lists precipitation data for selected stations in Sub-region D.

Average annual snowfall ranges from 17 inches at Mays Landing, N.J., to more than 75 inches at Roxbury, N.Y. Monthly variations in snowfall at selected stations in the Sub-region are shown on Table C-57. Some 40% to 60% of the total annual snowfall generally occurs in the months of January and February.

Major storms have either tropical origins, such as hurricanes, or extra-tropical origins. The most extensive storms are usually the storms of tropical origin occurring during late-summer and fall. The hurricanes of August 1955 produced the greatest flooding of record in the Sub-region. Heavy rains from Hurricane Connie, which occurred on August 12 and 13, produced from 11 to 12 inches of rain in parts of eastern Pennsylvania. Hurricane Diane on August 17-20 produced a total of about 15 to 16 inches within a period of 72 hours in some locations. Normally, showers and thunderstorms account for most of the precipitation during summer months.

The Sub-region has experienced numerous historical occurrences of sub-normal precipitation. One of the most severe years was 1930, when deficiencies of nearly 19 inches occurred. Because of its long duration, the drought of the 1960s was the most severe period of deficient rainfall. During the 59-month period from October 1961 to August 1966, the accumulated departure from normal precipitation varied from 36 inches in the headwaters to more than 60 inches in the central and southern parts of the Sub-region. Precipitation was about 75% of average during this period. Other droughts of shorter duration and lesser severity occurred in 1904, 1909, 1914, 1941 and 1957.

Temperature

The average annual temperatures vary from about 45° F. in the

TABLE C-56

PRECIPITATION DATA -SUBREGION D(in inches)

Station	Map Code	Years (a)	Elevation ft.,m.s.l.	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Annual
					Monthly Data												
Delhi,N.Y.	6	30	1,460	Max	5.01	4.48	5.09	5.14	8.28	6.62	12.89	11.80	10.22	7.75	9.01	6.10	
				Min	.95	1.05	1.58	1.77	1.07	1.56	1.31	1.08	.50	1.08	1.40	.75	
				Mean	2.75	2.66	3.09	3.32	3.89	3.92	4.62	4.21	3.90	3.45	3.56	2.86	42.23
Port Jervis,N.Y.	14	30	470	Max	5.50	4.85	7.93	9.10	8.76	8.62	11.35	18.04	8.43	9.60	7.45	6.93	
				Min	.98	.80	1.19	1.02	1.44	.90	.97	.79	.40	1.02	.71	.36	
				Mean	3.10	2.92	3.40	3.56	3.93	4.13	4.74	4.17	3.72	3.40	3.23	3.23	43.53
Bethlehem,Pa.	2	30	436	Max	6.22	5.54	6.36	8.20	9.68	9.98	11.97	12.02	10.80	7.85	7.05	5.90	
				Min	.65	1.47	1.25	.85	.86	.25	.22	.69	.21	.76	.69	.25	
				Mean	3.11	2.59	3.60	3.63	3.85	3.72	4.66	4.44	3.56	2.99	3.36	3.25	42.76
Trenton (#2),N.J.	5	30	105	Max	7.40	5.98	7.88	6.95	8.86	9.10	11.80	15.12	11.92	7.57	8.46	7.32	
				Min	.55	1.56	1.80	1.26	1.38	.20	.46	1.43	.26	.52	.77	.38	
				Mean	3.57	3.31	4.44	3.78	4.04	4.03	4.91	5.59	3.98	3.57	3.79	3.47	48.17
Tom's River,N.J.	11	23	10	Max	7.14	5.74	7.27	6.91	9.35	6.73	13.01	12.37	7.72	11.65	10.10	6.62	
				Min	.45	1.61	1.96	1.56	.77	.02	1.38	.36	0.00	.84	.25	.47	
				Mean	3.62	3.68	4.34	3.72	4.17	3.66	4.89	5.63	3.72	3.86	3.98	3.95	49.22
Phila. (Pt. Breeze),Pa.	1	30	32	Max	6.80	5.97	7.24	6.43	6.60	10.59	9.02	9.99	9.83	5.50	6.87	5.04	
				Min	.45	1.49	1.30	1.24	.82	.05	.77	.63	.80	.47	.61	.26	
				Mean	3.20	2.70	3.74	3.25	3.76	3.96	3.97	4.55	3.33	2.82	3.36	2.83	41.49
Wilmington,Del.	16	30	99	Max	7.45	5.90	6.87	6.47	7.47	8.37	9.94	11.16	8.26	6.21	8.11	6.00	
				Min	.46	1.47	1.46	1.12	.35	.29	.65	1.12	.45	.32	.72	.16	
				Mean	3.47	2.79	4.01	3.74	4.10	3.91	4.47	5.32	3.43	3.10	3.67	3.13	45.14
Mays Landing,N.J.	13	18	10	Max	6.82	8.22	7.32	7.27	11.96	5.82	12.86	9.27	8.42	4.97	7.22	7.44	
				Min	.56	1.47	1.71	1.62	.21	.41	.53	1.57	.47	.99	1.61	.61	
				Mean	3.44	3.42	4.01	3.24	4.16	2.94	5.24	5.25	3.44	2.94	4.07	3.77	45.92
Dover,Del.	15	30	30	Max	8.09	6.27	7.15	6.21	12.96	6.99	13.43	16.08	11.37	6.07	7.88	7.50	
				Min	.44	1.08	1.74	.83	.62	1.18	1.30	.85	T	.95	.79	.39	
				Mean	3.70	3.03	4.12	3.42	4.15	3.46	4.67	5.73	3.81	3.27	3.67	3.11	46.14
Cape May (3W), N.J.	4	30	17	Max	9.99	4.95	5.92	5.84	7.35	5.13	10.52	11.34	7.52	6.95	6.51	7.42	
				Min	1.13	.81	.47	1.73	.40	.13	.52	.42	.25	1.27	.53	.80	
				Mean	3.36	3.11	3.80	3.15	3.01	3.01	3.65	4.61	3.17	3.05	2.86	3.47	40.25
Newark WB,A.P., N.Y.	40	30	11	Max	6.33	5.88	8.49	6.41	8.12	6.19	7.96	11.84	10.28	8.20	7.41	6.84	
				Min	.81	1.46	1.95	1.15	.73	.07	1.14	1.91	.14	.89	.99	.27	
				Mean	3.33	2.80	4.09	3.51	3.65	3.44	3.67	4.43	3.76	3.11	3.37	3.22	42.38
Rahway,N.J.	41	26	20	Max	5.76	4.58	8.18	6.35	10.91	6.95	11.14	13.72	12.47	7.86	7.70	5.12	
				Min	.40	1.47	1.47	1.24	1.07	T	.72	1.98	T	.88	1.01	.06	
				Mean	2.98	2.73	3.88	3.51	4.06	3.24	4.86	4.71	3.51	3.00	3.64	3.14	43.26
Clinton,N.J.	42	22	200	Max	5.73	5.19	6.00	8.50	9.05	6.70	11.22	17.99	5.96	10.15	7.71	6.45	
				Min	.91	1.42	2.03	1.06	1.17	.21	.23	1.17	.48	.55	.74	.20	
				Mean	3.23	2.84	3.88	4.18	4.33	3.60	4.27	4.82	3.10	3.09	3.94	3.75	45.03
Long Branch,2N, N.J.	44	57	10	Max	7.28	6.76	7.68	7.30	9.07	6.94	16.17	10.97	11.81	9.53	9.12	8.87	
				Min	.64	1.50	1.78	1.48	.21	.04	.22	1.17	.03	.68	.45	.34	
				Mean	3.78	3.54	4.37	3.63	3.49	3.41	4.25	5.25	3.92	3.71	3.81	3.63	46.79

(a) Number of years thru 1960 used for monthly and average annual data.

TABLE C-57

SNOW DATA - SUBREGION D

Station	Map Code	Years of Record	Elevation ft.,m.s.l.	Average Snowfall in Inches (a)												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Roxbury,N.Y.	21	40	1492	18.1	17.7	16.2	6.5	.2	T	0	0	T	.9	5.5	12.3	77.4
Matamoras,Pa.	25	55	466	10.6	12.0	8.3	1.5	T	0	0	0	0	.1	2.2	8.8	43.5
Allentown,Pa.	18	17	254	6.9	7.3	6.9	.4	T	T	T	0	0	T	.9	6.9	29.3
George School,Pa.	23	52	150	6.9	7.2	4.9	1.1	T	T	T	0	0	T	.9	5.5	26.3
Trenton(W.B.)City,N.J.	5	88	105	6.2	7.3	4.1	.8	T	T	T	0	T	T	.8	4.6	23.8
Reading,Pa.	24	56	266	8.2	8.4	5.5	.8	T	T	0	0	0	T	1.2	5.5	29.6
Phila.(W.B.A.P.),Pa.	1	18	15	4.6	4.9	4.2	T	T	T	0	0	0	T	0.8	3.9	18.4
Wilmington, Del.	16	27	274	5.0	5.4	4.8	.1	T	T	0	0	0	T	0.9	3.8	20.1
Clayton,N.J.	12	47	134	6.2	5.6	3.5	.9	0	T	0	T	0	.1	1.0	4.6	21.9
Dover,Del.	15	60	25	4.9	5.1	2.9	.5	T	T	0	0	0	.1	.4	3.9	17.8
Little Falls,N.Y.	37	48	150	7.6	8.4	6.0	1.3	T	T	T	T	0	T	1.1	6.1	30.5
Morris Plains 1W,N.Y.	38	19	400	7.5	7.4	7.6	1.3	T	T	T	0	0	.1	.9	8.1	32.9
Long Valley,N.Y.	39	25	550	7.4	9.3	7.0	1.5	T	T	T	0	0	0	1.2	7.7	34.1
Newark WB AP,N.J.	40	30	11	6.1	6.9	5.4	.8	T	T	0	T	0	T	.9	6.4	26.5
Hightstown,1N,N.J.	43	55	100	6.7	7.7	4.3	1.0	0	0	T	0	0	T	1.0	4.8	25.5
Long Branch,2N,N.J.	44	48	10	6.1	7.0	5.0	.7	T	0	T	0	0	T	.4	5.0	24.2
Mays Landing,N.J.	13	13	50	4.2	5.6	4.0	.1	0	T	0	0	0	T	.7	2.4	17.0

(a) Data based on years of record through 1960 (third column).

headwaters to almost 55° F. along the coast. Normal temperatures range from 25° F. to 35° F. in winter, and from 70° F. to 75° F. during the summer. There is a wide variation of temperatures between southern and northern areas in the winter. In the north, the normal annual number of days with normal mean temperatures of 20°F-32°F is as much as 75, while the number of days with these same normal mean temperatures in the south is none. Table C-58 shows mean temperature data for selected stations.

Humidity

The mean relative humidity averages about 70% each year in the interior, and about 75% along the Sub-region's coast. Average January relative humidity is about 70%, and the July average is also about 70%.

The mean dew point temperature is between 35° F. and 45° F. annually, averaging between 20° F. and 25° F. in January, and between 60° F. and 65° F. in July. The annual average at both Trenton, N.J., and Philadelphia, Pa., is 43° F.

Wind

The generally prevailing wind direction during the winter is from the west and northwest, while during July it is from the west and southwest. Average velocities vary from about 10 m.p.h. along the coast to 8 m.p.h. inland. Maximum winds of greater than 75 m.p.h. have occurred during severe storms, such as hurricanes.

Evaporation

Normal annual lake evaporation ranges from about 28 inches to 38 inches, north and south, in the Sub-region. Approximately 73% of the annual evaporation occurs from May to October. Evaporation in July totals about 5 inches.

HYDROLOGY

Existing Resource

Hydrologic Records. Currently, surface water records at approximately 190 stations are compiled and published by the U.S. Geological Survey, in cooperation with the several States. Approximately 120 gages are located in Area 15, and 70 gages in Areas 14 and 16. Additional data are available from "Daily River Stages", published by the National Weather Service, and from miscellaneous reports of the Delaware River Joint Toll Bridge Commission. Selected streamflow gaging stations referred to in this Appendix are

TABLE C-58

TEMPERATURE DATA (a) -SUBREGION D (in degrees Fahrenheit)

Station	Map Code	Years of Record	Elevation ft.,m.s.l.	Item	Annual Means	Monthly Means											
						Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Delhi,N.Y.	6	36	1,460	Mean Max	57.3	33.1	34.6	42.4	55.9	68.2	76.9	81.0	79.2	72.3	61.4	47.6	35.3
				Mean Min	34.3	14.0	13.9	21.2	31.9	41.5	50.8	55.1	53.5	47.2	36.7	28.7	17.1
				Mean(b)	46.0	23.7	23.9	31.6	44.2	55.4	64.2	68.4	66.6	59.8	49.5	38.1	26.2
Port Jervis,N.Y.	14	74	470	Mean Max	60.5	35.1	36.4	46.6	60.5	72.3	80.5	84.8	82.2	75.6	64.4	50.0	37.7
				Mean Min	38.2	17.6	17.4	25.8	35.9	46.2	54.8	59.7	57.9	51.3	40.0	30.7	21.1
				Mean	49.2	26.1	26.8	35.7	47.9	59.2	67.6	72.1	69.9	63.4	52.1	40.2	29.3
Allentown,Pa.	18	30	370	Mean Max	61.8	38.0	39.3	47.6	60.6	72.2	80.7	85.4	83.0	76.3	65.8	56.2	40.4
				Mean Min	41.7	22.1	21.7	28.8	39.4	49.5	58.7	63.5	61.5	53.7	43.1	33.6	24.2
				Mean	51.7	30.1	30.5	38.2	50.0	60.9	69.7	74.5	72.2	65.0	54.4	43.1	32.3
Trenton,N.J.	5	88	105	Mean Max	62.4	39.6	40.3	49.6	61.0	72.1	80.4	84.9	82.5	76.3	65.8	53.4	42.3
				Mean Min	45.0	25.5	24.9	32.7	41.8	52.0	60.9	66.4	64.6	58.1	47.6	37.7	28.2
				Mean(b)	58.9	33.1	33.4	40.7	51.7	62.3	71.0	76.0	73.9	67.1	56.8	45.8	35.2
Phila(Pt.Breeze),Pa.	1	28	32	Mean Max	64.1	41.2	43.0	51.1	63.0	74.0	82.4	86.5	84.3	78.1	67.5	55.2	43.4
				Mean Min	48.1	28.5	28.9	35.3	44.5	55.3	64.0	69.2	67.6	61.4	51.0	40.6	30.7
				Mean	56.1	35.1	35.8	42.9	53.7	64.6	73.2	77.8	76.0	69.8	59.2	48.0	37.3
Wilmington,Del., Porter,Res.	16	29	260	Mean Max	62.9	40.1	43.3	48.2	63.1	71.8	80.5	85.3	82.8	76.6	66.3	53.2	43.0
				Mean Min	44.5	25.7	25.2	31.8	41.3	51.7	60.8	65.5	64.1	57.5	47.0	36.6	27.2
				Mean	53.9	33.4	33.7	41.1	51.8	62.4	71.0	75.4	73.8	67.4	56.9	45.4	35.0
Cape May,N.J.	4	46	17	Mean Max	61.1	42.3	41.6	46.4	57.6	67.3	75.7	80.8	79.9	75.4	66.3	55.1	44.2
				Mean Min	47.6	28.6	28.5	34.9	43.5	52.9	61.6	67.2	66.8	61.7	52.0	41.4	31.7
				Mean(b)	54.6	35.5	35.8	41.9	51.1	59.4	69.2	74.4	73.7	68.9	59.5	48.2	38.0
Long Valley,N.J.	39	24	550	Mean Max	61.4	37.5	39.0	47.1	60.9	71.3	79.7	84.5	81.7	75.7	66.2	52.7	40.3
				Mean Min	38.1	19.2	19.3	26.4	36.3	45.0	54.3	59.0	57.0	50.3	39.7	29.9	20.9
				Mean	49.1	29.3	29.2	36.8	48.6	58.3	67.0	71.7	69.4	63.0	52.9	41.7	30.6
Long Branch,N.J.	44	51	10	Mean Max	60.6	39.9	40.0	47.7	57.5	67.9	76.6	81.8	80.1	74.4	64.7	53.2	43.4
				Mean Min	44.1	24.9	24.6	31.6	40.6	50.3	59.7	65.1	63.8	57.8	46.9	36.9	27.4
				Mean(b)	52.9	33.0	33.0	39.8	49.6	59.8	69.1	74.4	72.8	66.2	56.2	45.7	35.3

(a) Based on period of record through 1960 except as otherwise noted.
(b) Data based on period 1931-60.

located on Figure C-37.

Average Flow. The average flow amounts to 28,270 c.f.s. from the Sub-region's 17,534 square miles of drainage area. This is the equivalent of 21.9 inches runoff, which represents approximately 49% of the total precipitation. Runoff, on a per square mile basis, is highest in Sub-area 15a at 1.8 c.s.m., and lowest in Sub-area 15d at 1.4 c.s.m. The Sub-regional average is 1.6 c.s.m. Table C-59 shows estimated average runoff for each Sub-area.

TABLE C-59
AVERAGE ANNUAL RUNOFF - SUB-REGION D
(Drainage area in square miles, average runoff in c.f.s.)

	DRAINAGE AREA	AVERAGE RUNOFF
AREA 14	2,376	3,990
Sub-area 15a	3,480	6,310
Sub-area 15b	3,533	5,900
Sub-area 15c	1,147	1,840
Sub-area 15d	4,605	6,375
AREA 15	12,765	20,425
Sub-area 16a	372	670
Sub-area 16b	2,021	3,125
AREA 16	2,393	3,795
SUB-REGION D	17,534	28,270

Streamflow Variation. Maximum monthly flows have occurred most frequently in March and April in the Delaware River Basin, and most frequently in March in the northern New Jersey streams and along the New Jersey Coast. Magnitudes are generally on the order of five times the average, except along the New Jersey Coast, where less variation exists. Minimums occur most in August and September, and occasionally in October, and are generally between 5% and 10% of average flow Table C-60 lists average, maximum and minimum monthly flows for selected stations.

Existing Regulation. Sub-region D contains about 1.8 million acre-feet of existing storage, or about 11% of the North Atlantic Region's total. The 400,000 acre-feet of storage in Area 14 is operated almost exclusively for municipal supply and power with

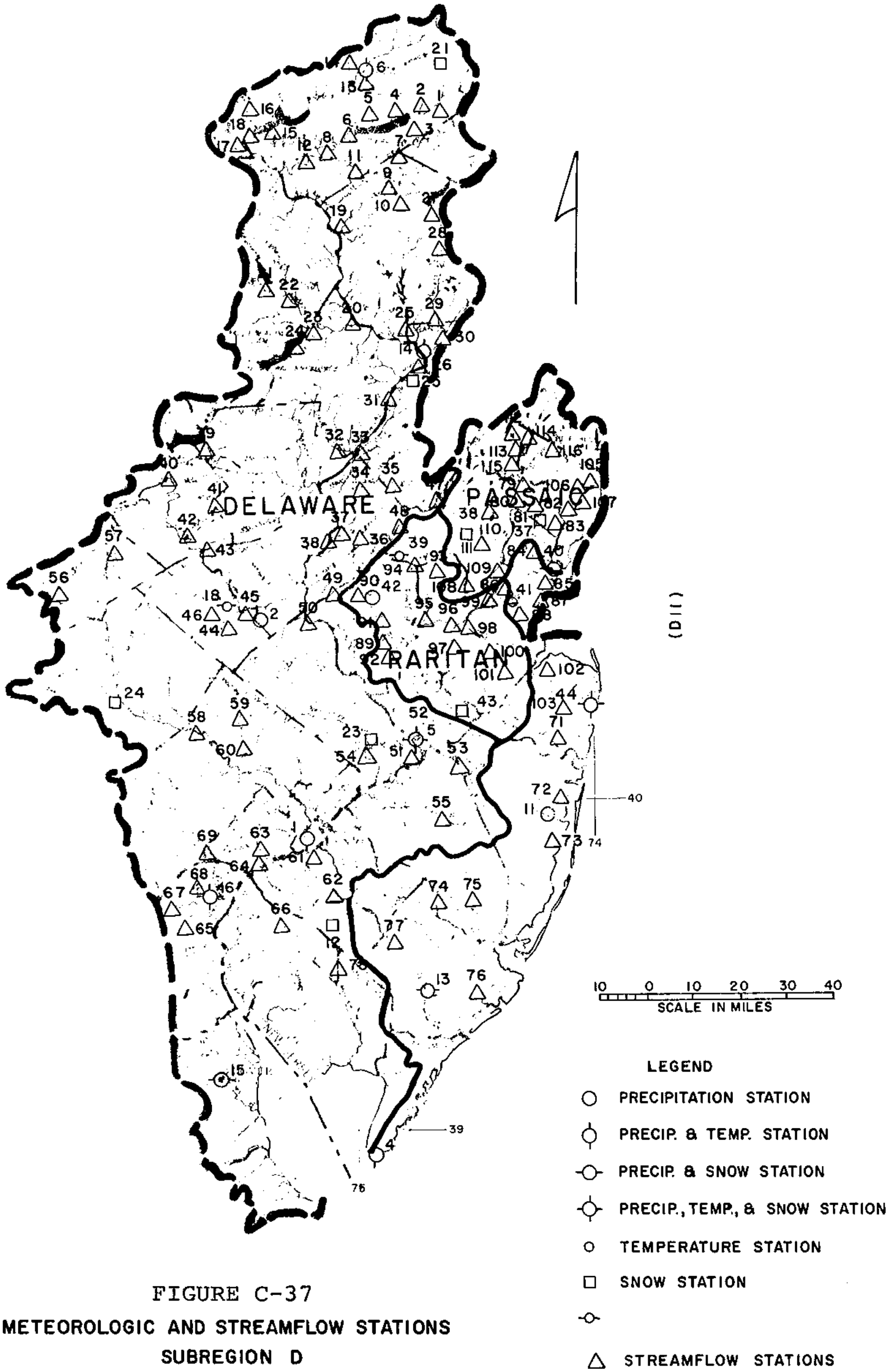


FIGURE C-37
METEOROLOGIC AND STREAMFLOW STATIONS
SUBREGION D

TABLE C-60

STREAMFLOW DATA (a) - SUBREGION D

Station	Map Code	D.A., sq.mi.	Years of Record	Average(b) Flow-c.f.s.	Mean Monthly Flow-c.f.s.(c) Maximum	Date	Minimum	Date	Structures Affecting Natural Streamflow
E. Branch Del. R. at Margaretsville, N.Y.	1	163	28	294	1,808	4/58	15.5	9/43	
Little Beav. Kill nr. Livingst'n Manor, N.Y.	10	19.8	41	44.0	284	3/36	2.33	8/57	Some diversion
Beaver Kill at Cooks Falls, N.Y.	11	241	51	547	2,581	4/40	43.7	8/57	
E. Branch Del. R. at Fishs Eddy, N.Y.	12	783	42(thru '54)	1,681	10,500	4/14	113	8/54	Pepacton Reservoir
Cold Spring Brook at China, N.Y.	16	1.51	31	2.59	16.0	4/56	0.02	8/53	
W. Branch Del. R. at Hale Eddy, N.Y.	18	593	47(thru '60)	1,066	5,416	4/36	49.6	8/13	Connonsville Reservoir after 10/63
Wallenpaupack Cr. at Wilsonville, Pa.	24	288	56	358	-	-	-	-	Lake Wallenpaupack
Lackawaxen R. at Howley, Pa.	23	290	36	470 *	2,553	4/58	32.1	8/57	Prompton & Jadwin Res.
Neversink R. at Oakland Valley, N.Y.	29	222	24(thru '52)	478	2,342	5/36	55.1	9/53	Neversink Res. after 6/53
Del. R. at Port Jervis, N.Y.	26	3,076	58(thru '54)	5,572	28,470	3/36	357	9/08	Several reservoirs, diversion
Del. R. at Montaque, N.J.	31	3,480	26	5,935	24,480	5/45	71.5	9/54	Several reservoirs, diversion
Bush Kill at Shoemakers, Pa.	32	117	57	231	1,119	5/36	8.52	8/57	
Flat, Brook nr. Flatbrookville, N.J.	33	65.1	42	107	513	5/36	9.53	9/43	
Paulins Kill at Blairstown, N.J.	34	126	44	187	963	3/36	19.7	8/57	
Pequest R. at Pequest, N.J.	36	108	44	147	750	3/36	21.4	9/32	
Beaver Brook nr. Belvidere, N.J.	37	36.2	38(thru '60)	52.3	283	3/36	2.05	9/57	
Del. R. at Belvidere, N.J.	38	4,535	43	7,866	42,520	3/36	881	8/54	Several reservoirs, diversion
Lehigh R. at Tannery, Pa.	40	322	45(thru '59)	667	3,467	3/36	46.2	9/36	
Lehigh R. at Bethlehem, Pa.	45	1,279	58	2,247 *	11,920	3/36	308	10/10	Several reservoirs
Musconetcong R. nr. Hackettstown, N.J.	48	70.0	44	117	386	4/58	8.87	8/57	Lake Hopetcong
Musconetcong R. nr. Bloomsbury, N.J.	49	143	47	222	955	3/36	42.3	8/57	Lake Hopetcong
Delaware R. at Riegelsville, N.J.	50	6,328	59	10,960	58,250	3/36	1,250	9/08	Several reservoirs, diversion
Assumpink Cr. at Trenton, N.J.	52	89.4	42	118	426	3/36	15.8	9/43	Some diversion
Delaware R. at Trenton, N.J.	51	6,780	53	11,550	60,840	3/36	1,632	10/41	Several reservoir, diversion
N. Branch Rancocas Cr. at Pemb'ton, N.J.	55	111	44	167	469	3/58	38.7	10/22	Some regulation by dam & ponds
Little Schuylkill R. at Tamaqua, Pa.	57	42.9	46	92.7 *	410	3/20	6.27	8/44	Still Creek Reservoir after 2/33
Schuylkill R. at Pottstown, Pa.	58	1,147	39	1,837	8,948	3/36	256	8/32	
Perkiomen Cr. at Graterford, Pa.	60	279	51	374 *	2,193	3/36	21.0	8/30	Green Lane Res. after 12/56
Schuylkill R. at Philadelphia, Pa.	61	1,893	34	2,852 *	13,320	3/36	89.4	10/43	Several reservoirs, diversion
Ridley Cr. at Moylen, Pa.	63	31.9	23(thru '54)	43.3	146	3/36	4.74	9/41	Some Diversion
Chester Cr. nr. Chester, Pa.	64	61.1	34	79.9	236	4/58	10.4	9/32	
Brandywine Cr. at Chadds Ford, Pa.	69	287	45	379	1,303	3/36	59.4	9/32	

TABLE C-60 CONT.

STREAMFLOW DATA (a) - SUBREGION D

Station	Map Code	D.A., sq.mi.	Years of Record	Average(b) Flow-c.f.s.	Mean Monthly Flow-c.f.s.(c) Maximum	Date	Minimum	Date	Structures Affecting Natural Streamflow
Oswego R. at Harrisville, N.J.	75	64.0	35	87.3	220	3/58	23.9	8/57	
Gt. Egg Hbr. R. at Folsom, N.J.	77	56.3	40	84.4	228	2/39	19.9	8/57	
Maurice R. at Norma, N.J.	78	113	33	169	591	9/40	36.2	8/57	
Hackensack R. at New Milford, N.J.	107	113.0	44	115	651	3/36	0	10/49	Several lakes, diversion
Passaic R. nr. Millington, N.J.	108	55.4	45	85.1	430	3/36	0.73	9/64	Diversion
Passaic R. nr. Chatham, N.J.	109	100.0	36	160	700	3/07	4.7	9/06	Diversion
Whippany R. at Morristown, N.J.	111	29.4	44	48.5	215	3/36	7.23	9/32	Pocahontas Dam
Wanaque R. at Awesting, N.J.	112	27.1	46	50.5	256	3/36	0	8/29	Greenwood Lake
West Brook nr. Wanaque, N.J.	115	11.8	31	23.0	119	3/36	0.86	9/64	
Ramapo R. nr. Mahwah, N.J.	116	118.0	47	223	1,151	3/36	11.1	9/64	
Ramapo R. at Pompton Lakes, N.J.	79	160.0	44	290 *	1,670	3/36	108	9/64	Diversion to Wanaque Res. since 1953
Passaic R. at Little Falls, N.J.	81	762	68	1,160	6,755	3/36	28.9	9/64	Several reservoirs, diversions
Saddle R. at Lodi, N.J.	82	54.6	42	95.5	323	3/36	16.5	8/35	
Elizabeth R. at Eliz., N.J.	85	18.0 net	44	23.6	107	8/55	0.07	8/23	Ursina Lake, diversions
Rahway R. at Rahway, N.J.	87	40.9	44	43.7	170	3/36	0.43	8/64	Water supply diversions
Weshonic R. at Reaville, N.J.	92	25.7	35	33.6	179	3/36	0.44	8/64	
So. Branch Raritan R. nr. High Bridge, N.J.	90	65.3	47	115	466	3/36	20.4	8/65	
So. Branch Raritan R. at Stanton, N.J.	91	147.0	49	234	1,057	3/36	30.1	8/57	Spruce Run Res. (1963)
Manasquan R. at Squankum, N.J.	71	43.4	34	71.4	282	3/58	16.6	9/32	
Toms R. nr. Toms R., N.J.	72	124	37	209	541	3/58	75.4	9/41	
No. Branch Raritan R. nr. Far Hills, N.J.	93	26.2	44	45.8	207	3/36	3.61	9/64	
No. Branch Raritan R. nr. Rar., N.J.	95	190.0	42	287	1,272	3/36	14.8	9/64	
Raritan R. at Manville, N.J.	96	490.0	47	732	3,260	3/36	50.5	8/32	Diversion
Millstone R. at Blackwells Mills, N.J.	97	258.0	44	359	1,303	3/36	25.9	8/57	Lake Carnegie
Lawrence Brook at Farrington Dam, N.J.	100	34.4	38	37.8 *	142	3/36	0.0	11/63	Farrington Reservoir
Swimming R. nr. Red Bank, N.J.	103	48.5	43	76.4 *	179	3/62	0.0	8/57	Swimming R. Res., div. for water supply

(a) Based on observed flows except for data with asterisks (*) which have been adjusted for some effects of regulation.
(b) Based on records thru Water Year 1965 except where shorter records are indicated in the sixth column.
(c) Unless shorter record is indicated in sixth column, data for stations numbered 1 through 78 based on records through Water Year 1960; data for stations numbered 79 through 116 based on records through Water Year 1965.

Note: Stations are not necessarily listed in the usual downstream order. Refer to map code number sequences.

although hardness, some flood control and recreation use. Major storage in Area 16 is negligible. Table C-5 (p. C-23) summarizes existing major storage by Area.

About 857,000 acre-feet of the storage in Area 15 is in three New York City reservoirs in the upper Delaware River. Popacton Reservoir, on the East Branch of the Delaware, impounds water for diversion through the East Delaware Tunnel to Rondout Reservoir, on Rondout Creek in the Hudson Basin. Neversink Reservoir on the Neversink River, impounds water for diversion through the Neversink-Grahamsville Tunnel to Rondout Reservoir, and Cannonsville Reservoir, on the West Branch Delaware River, impounds water for diversion through the West Delaware Tunnel to Rondout Reservoir. All three of these diversions are for water supply, mostly for the City of New York, and the amounts of diversion vary widely from month to month. Generally, larger diversions are made during the low flow months in the summer. During calendar year 1970, the total diversion from the three reservoirs averaged just over 900 c.f.s. Data on firm yield of the New York City reservoirs is given in the Water Availability Analyses section of the Sub-region C Summary.

Another diversion from the Delaware Basin is through the Delaware and Raritan Canal to the Raritan River at New Brunswick, N.J., for municipal and industrial use. Flow in this Canal at Kingston, N.J., averaged about 59 m.g.d. in Water Year 1965. The maximum monthly flow was 66 m.g.d. in June and September. The safe capacity of the canal is estimated to be about 75 m.g.d. A smaller interbasin diversion (about 25 m.g.d.) exists to transfer water from Octoraro Creek in Area 17 to the Chester, Pa., area in Area 15.

Quality and Suitability. The surface waters of Sub-region D are mostly of the calcium-magnesium type, except for some coastal areas in New Jersey and Delaware, where waters could be classed as the sodium-potassium type. In general, the waters of most northern New Jersey streams, are harder than the water in the remainder of the Sub-region. Average suspended sediment concentrations are moderate, except in the upper Schuylkill where they are relatively high. Annual sedimentation rates vary from 51 tons per square mile in Area 16 to 123 tons per square mile in Area 14. (See Appendix Q, Erosion and Sedimentation.)

Industrial and non-industrial waste sources contributed about 14 million population equivalents (PE) of biodegradables, as measured by biochemical oxygen demand (BOD), to the waters of the Sub-region in 1960. (See Appendix L, Water Quality and Pollution.) Water quality problem areas include the lower Hackensack, Passaic and Raritan Rivers, Raritan Bay in Area 14 and the Delaware River estuary in Area 15. Acid mine drainage creates problems in the upper Lehigh and Schuylkill Rivers.

Floods. During this century, some of the most severe flooding in Sub-region D has occurred in 1903, 1933, 1935, 1936, 1938, 1942 and 1955. Floods can occur at any time of the year, but hurricane-caused flooding in the fall and flooding caused by a combination of precipitation and snowmelt in the spring have proven the most severe. The hurricane-flood on August 19, 1955, created new maximum stage and discharge records along all points of the mainstem Delaware River. The peak flow at Trenton, N.J., was 329,000 c.f.s. and at Port Jervis, N.Y. 233,000 c.f.s., replacing respective previous highs of 295,000 c.f.s. and 205,000 c.f.s., which occurred on October 10 and 11, 1903. Maximum recorded floods for selected stations in the Sub-region are listed in Table C-61. Peak flow frequency data for selected stations are listed in Table C-3 (p. C-17).

Low Flow. The most prolonged and severe drought occurred between 1960 and 1966, affecting the entire Sub-region. This drought was particularly severe, with many record lows established. Another severe drought occurred in the 1930s, producing low flows throughout the Sub-region. A comparison of these droughts shows that the annual flow on the Schuylkill River at Pottstown, Pa., was 50% of average in Water Year 1931, 60% in 1932, 45% and 53% respectively, in Water Years 1965 and 1966. On the Delaware River at Trenton, N.J., the flow was about 68% of the long-term average in Water Years 1931 and 1932, and 56% of average for the period covering Water Years 1964 through 1966. Other droughts in this century, as listed in various sources, occurred in 1900, 1904, 1908, 1909, 1914, 1922, 1941 and 1957.

Ground Water. Much of the ground water resource of the Sub-region lies in the Coastal Plain, which is bounded by the coastline and a line running generally southwest between Rahway and Trenton, N.J., crossing into Pennsylvania and running parallel to, and slightly inland of, the Delaware River. The most productive aquifers are in the Raritan and Magothy formations and the Cohansey sands. Yields are generally 500 g.p.m. or greater. The Appalachian Highlands lie northwest of the fall line and consist of bedrock with glacial aquifers in the northern part of the Sub-region. The consolidated rock areas are not highly productive. However, wells in glacial outwash can sustain yields of up to 1 m.g.d. or so in some instances.

Ground water quality is generally suitable for most uses. In upland areas, hardness is moderate to high, increasing in a northwesterly direction. Except for this hardness, waters are of good quality, with some localized iron and sulfate content problems. Quality is generally very good in coastal areas,

TABLE C-61

FLOOD DATA - SUBREGION D

Location	Map Code	Latest Data (W.Year)	Flood No. 1 Date	Flood No. 1 Peak Q. c.f.s.	Flood No. 1 Stage, ft.	Flood No. 1 $Q/(D.A.)^{.5}$	Flood No. 2 Date	Flood No. 2 Peak Q. c.f.s.	Flood No. 2 Stage, ft.	Flood No. 2 $Q/(D.A.)^{.5}$	Flood No. 3 Date	Flood No. 3 Peak Q. c.f.s.	Flood No. 3 Stage, ft.	Flood No. 3 $Q/(D.A.)^{.5}$
E. Branch Del. R. at Margaretsville, N.Y.	1	1965	11/25/50	15700	13.84	1230	10/16/55	13300	12.87	1040	9/21/38	13200	11.74	1030
Little Beav. Kill nr. Livingst'n Manor, N.Y.	10	1965	8/26/28	3420	8.70	770	8/24/33	3180	8.60	720	3/18/36	3120	8.50	700
Beaver Kill at Cooks Falls, N.Y.	11	1965	3/31/51	31600	16.02	2040	11/26/50	29400	15.52	1900	12/21/57	28900	15.42	1860
E. Branch Del. R. at Fishs Eddy, N.Y.	12	1965	8/24/33	53300	20.60	1900	3/18/36	46000	19.21	1640	9/30/24	45000	19.00	1610
Cold Spring Brook at China, N.Y.	16	1965	10/30/35	335	4.50	270	11/13/35	258	4.24	210	3/22/48	179	3.88	150
W. Branch Del. R. at Hale Eddy, N.Y.	18	1965	3/22/48	28900	15.69	1180	9/30/24	26500	15.80	1090	3/18/36	25900	14.22	1060
Wallenpaupock Cr. at Wilsonville, Pa.	24	1965	3/29/14	4840	-	320	4/ 7/24	4550	4.65	300	3/ 9/22	4400	4.50	290
Lackawaxen R. at W. Howley, Pa.	104	1938	5/23/42	38000	22.30	2650	4/18/36	18300	15.32	1280	4/12/36	10400	11.40	730
Lackawaxen R. at Hawley, Pa.	23	1965	8/19/55	51900	20.6	3050	5/23/42	50000	20.1	2940	7/10/52	21700	11.78	1270
Neversink R. at Oakland Valley, N.Y.	29	1965	8/14/55	23800	12.74	1600	11/26/50	23300	12.62	1560	8/24/33	22600	12.61	1520
Del. R. at Port Jervis, N.Y.	26	1965	8/19/55	233000	23.91	4200	10/10/03	205000	23.10	3690	5/23/42	140000	17.76	2520
Del. R. at Montague, N.Y.	31	1965	8/19/55	250000	35.15	4240	3/18/36	164500	28.45	2790	5/23/42	136500	25.70	2310
Bush Kill at Shoemaker, Pa.	32	1965	8/19/35	23400	13.95	1800	7/24/20	5250	7.20	400	3/18/36	4770	6.95	370
Flat Brook nr. Flatbrookville, N.J.	33	1965	8/19/55	9560	12.58	1190	4/ 6/52	3170	7.24	390	2/11/25	3040	7.10	380
Paulins Kill at Blairstown, N.J.	34	1965	8/19/55	8750	11.20	780	9/22/38	4480	7.56	400	10/16/55	3740	7.76	330
Pequest R. at Pequest, N.J.	36	1965	3/14/36	1810	4.97	170	7/23/45	1340	4.18	120	3/15/40	1330	4.17	120
Beaver Brook nr. Belvidere, N.J.	37	1961	3/12/36	1510	5.76	250	3/15/40	1020	4.80	170	8/17/42	910	4.60	150
Del. R. at Belvidere, N.J.	38	1965	8/19/55	273000	30.21	4050	10/10/03	220000	28.6	3270	3/19/36	179000	25.00	2660
Lehigh R. at Tannery, Pa.	40	1959	8/19/55	58300	22.20	3260	5/22/42	29600	16.51	1630	3/12/36	20000	13.34	1115
Lehigh R. at Bethlehem, Pa.	45	1965	5/23/42	92000	23.47	2570	8/19/55	91300	23.38	2550	2/28/02	88000	24.90	2460
Musconetcong R. nr. Hackettstown, N.J.	48	1965	8/19/55	2170	3.97	260	3/12/36	1430	5.88	170	7/10/35	1290	5.55	150
Musconetcong R. nr. Bloomsbury, N.J.	49	1965	10/10/03	6960	8.00	540	3/15/40	5760	7.55	440	5/20/40	5500	7.44	420
Delaware R. at Riegelsville, N.J.	50	1965	8/19/55	340000	38.85	4280	10/10/03	275000	35.90	3470	3/19/36	237000	32.45	3000
Assumpink Cr. at Trenton, N.J.	52	1965	9/22/38	3320	10.74	350	8/13/55	2400	9.29	250	4/ 7/24	2400	7.85	250
Delaware R. at Trenton, N.J.	51	1965	8/20/55	329000	20.83	3980	10/11/03	295000	20.70	3570	3/19/36	227000	16.66	2750
N. Branch Rancocos Cr. at Pemb'ton, N.J.	55	1965	8/21/39	1730	10.77	160	9/22/38	1680	10.56	160	9/13/60	1420	3.81	130
Little Schuylkill R. at Tamaque, Pa.	57	1965	8/18/55	7790	11.10	1180	9/30/24	5000	7.50	760	5/22/42	4310	7.95	660
Schuylkill R. at Pottstown, Pa.	58	1965	2/28/02	53900	21.00	1580	5/23/42	50800	20.15	1490	8/24/33	47800	19.20	1410
Perkiomer Cr. at Graterford, Pa.	60	1965	7/ 9/35	39900	18.26	2390	8/23/33	34600	16.65	2080	6/ 2/46	31700	16.23	1900
Schuylkill R. at Philadelphia, Pa.	61	1965	10/ 4/1869	135000	17.00	3110	3/ 1/02	98000	14.80	2250	8/24/33	96200	14.70	2210
Ridley Cr. at Moylen, Pa.	63	1955	11/25/50	5720	10.84	1010	8/18/55	4390	9.42	780	7/23/38	3320	8.16	590
Chester Cr. nr. Chester, Pa.	64	1965	11/25/50	14400	16.21	1840	9/12/60	9940	13.89	1270	8/18/55	9380	13.57	1200
Brandywine Cr. at Chadds Ford, Pa.	69	1965	3/ 5/20	17200	15.00	1010	8/ 9/42	16800	14.80	990	8/ 4/15	16500	14.70	970

TABLE C-61 CONT.

FLOOD DATA - SUBREGION D

Location	Map Code	Latest Data (W.Year)	Flood No. 1				Flood No. 2				Flood No. 3			
			Date	Peak Q. c.f.s.	Stage, ft.	Q/(D.A.)$^{.5}$	Date	Peak Q. c.f.s.	Stage, ft.	Q/(D.A.)$^{.5}$	Date	Peak Q. c.f.s.	Stage, ft.	Q/(D.A.)$^{.5}$
Manasquan R. at Squankurn, N.J.	71	1965	9/12/38	2490	12.45	450	9/15/44	2360	10.15	360	10/27/43	2360	10.15	360
Toms R. nr. Toms R., N.J.	72	1965	9/23/38	2000	12.50	130	6/29/38	1440	11.10	90	9/14/60	1370	10.57	90
Batsto R. at Batsto, N.J.	74	1965	8/24/33	1310(a)	7.25	160	4/29/52	1130(a)	6.27	130	8/26/58	1100(a)	7.10	130
Oswego R. at Harrisville, N.J.	75	1965	8/20/39	1390	9.54	170	9/21/38	988	8.18	120	8/24/33	859	6.96	110
Gt. Egg Hbr. R. at Folsom, N.J.	77	1965	9/ 3/40	1440	9.09	190	9/23/38	718	6.59	100	8/25/33	700	7.56	90
Maurice R. at Norma, N.J.	78	1965	9/ 2/40	7360	8.72	690	9/14/60	1370	5.03	130	8/27/58	1200	4.80	110
Hackensack R. at New Milford, N.J.	107	1965	3/31/51	3660	6.14	350	10/16/55	3460	5.89	330	9/12/60	2930	5.24	280
Passaic R. nr. Millington, N.J.	108	1965	10/10/03	2000	7.80	260	1/ 9/05	2000	7.80	260	7/24/19	2000	7.80	260
Passaic R. nr. Chatham, N.J.	109	1965	1/ 9/05	3000	8.30	300	3/18/07	2860	8.00	290	10/11/03	2310	-	230
Whipanny R. at Morristown, N.J.	111	1965	10/ 9/03	3200	-	590	8/26/28	2000	7.30	370	11/19/32	1820	7.00	340
Wanaque R. at Awesting, N.J.	112	1965	10/16/55	1300	5.85	250	3/31/51	1190	5.41	230	8/19/55	1160	5.58	220
West Brook nr. Wanaque, N.J.	115	1965	3/30/51	1900	6.60	550	3/11/36	1450	5.80	420	8/19/55	1200	5.73	350
Ramapo R. nr. Mahwah, N.J.	116	1965	10/ 9/03	12400	11.00	1140	10/16/55	10900	12.53	1000	8/19/55	8580	11.35	790
Ramapo R. at Pompton Lakes, N.J.	79	1965	10/ 9/03	15800	-	1260	3/21/36	12300	3.56	980	10/16/55	12000	4.40	950
Passaic R. at Little Falls, N.J.	81	1965	10/10/03	28000	-	1190	3/ 2/02	21400	-	780	7/23/45	19500	-	710
Saddle R. at Lodi, N.J.	82	1965	10/ -/03	7000	-	950	7/23/45	3500	10.00	470	3/31/51	2530	7.27	340
Elizabeth R. at Eliz., N.J.	85	1966	7/29/1897	5200(b)	-	1230	10/ 9/03	3750(b)	-	880	7/23/38	2720	13.05	640
Rahway R. at Rahway, N.J.	87	1965	7/24/38	3140	6.35	490	8/13/55	2440	5.63	380	9/12/60	1850	4.99	290
Neshanic R. at Reaville, N.J.	92	1965	7/18/45	10300	12.33	2030	8/ 9/42	9150	12.00	1800	8/19/55	8830	11.90	1740
So. Branch Raritan R. nr. High Bridge, N.J.	90	1965	3/15/40	5160	11.78	640	2/ 2/22	3600	10.97	440	3/11/36	3080	10.51	380
So. Branch Raritan R. at Stanton, N.J.	91	1965	8/19/55	18000	15.22	1490	10/14/55	11700	12.55	970	7/19/45	10900	12.20	900
No. Branch Raritan R. nr. Far Hills, N.J.	93	1965	3/15/40	3410	5.85	670	8/10/42	3280	5.75	640	10/14/55	2710	5.33	530
No. Branch Raritan R. nr. Rar., N.J.	95	1965	8/19/55	20700	13.59	1500	10/15/55	17300	12.68	1260	9/21/38	16500	12.16	1200
Raritan R. at Manville, N.J.	96	1965	9/22/38	36100	20.42	1640	8/19/55	34600	22.10	1570	8/ 9/42	33200	19.70	1500
Millstone R. at Blackwells Mills, N.J.	97	1965	9/21/38	18300	15.29	1140	12/31/48	14000	13.84	870	6/ 3/46	10500	12.37	660
Lawrence Brook at Farrington Dam, N.J.	100	1965	9/21/38	2660	26.18	450	7/ 6/28	1900	1.84	320	7/24/59	1610	25.85	280
Swimming R. nr. Red Bank, N.J.	103	1965	10/27/43	8910	8.96	1280	9/12/60	5700	8.46	820	8/13/55	3900	6.56	560

(a) Maximum daily mean discharge
(b) Estimated by unit hydrograph method.
Note: Stations are not necessarily listed in the usual downstream order. Refer to map code number sequences.

and iron and manganese content are objectionable in some places. Many wells have become salty, largely because of excessive pumping in locations near salt water bodies.

Estuaries and Coastal Areas. Estuarine waters in Sub-region D include the lower Delaware River and Delaware Bay, extending from Cape May and Cape Henlopen to Trenton. The Bay covers more than 700 square miles, with an overall length of about 50 miles and a maximum width of some 27 miles. Its mean depth is about 32 feet, with depths as much as 150 feet in some places. Estuary tides range from 4 feet at the Capes to about 7 feet at Trenton. The tides are affected by storm conditions and have reached heights of about 13 feet above normal high water at Trenton. Wave heights near the Capes have been reported as high as 15 feet during coastal storms.

The New Jersey shorelines, which is about 125 miles in length from Sandy Hook to Cape May, consists mostly of long, sandy barrier beaches and islands separated from the mainland by tidal marshes, bays and lagoons. Tidal ranges along the shore vary from 4.5 feet at Sandy Hook to 0.5 feet in parts of Barnegat Bay.

Water Availability Analyses

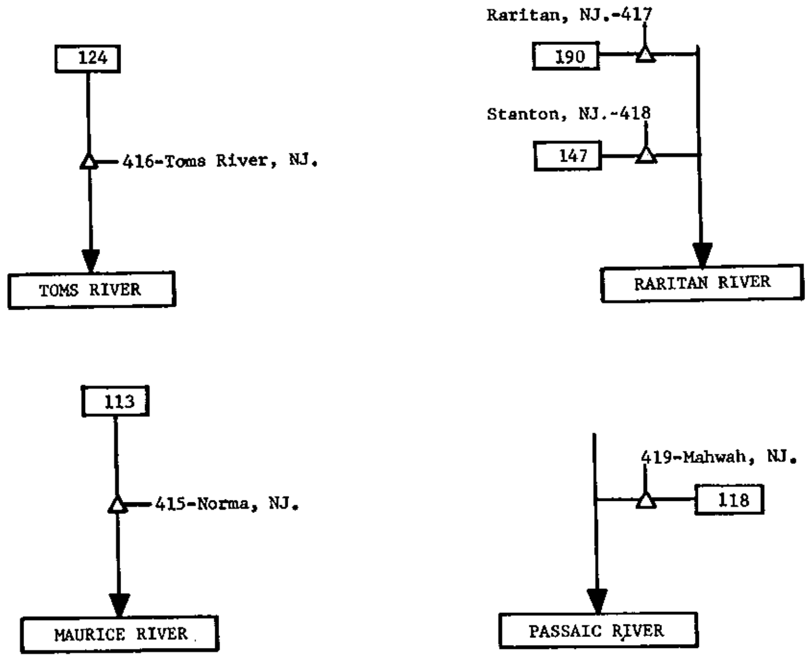
Evapotranspiration. The normal annual evapotranspiration in Sub-region D ranges from about 23 inches in the headwaters of the Delaware River to about 27 inches in the extreme southeastern end of the Sub-region, with an average of about 25 inches. The normal annual July evapotranspiration is between 5 and 6 inches and the reservoir surface evaporation for the same month is about 5 inches. Average annual lake evaporation is about 32 inches. The average net loss from reservoir surfaces, or the evaporation minus the evapotranspiration from the area a reservoir replaces, would be about 7 inches. This figure would vary widely depending upon local site characteristics. However, there may be net gains on a seasonal, or other short-term basis, due to the direct interception of precipitation on the lake surface, instead of first seeping into the ground.

Streamflow Simulation. Estimation of missing monthly streamflows and the extension of records of stations by correlation with longer record base stations was accomplished by the methods covered in Chapter 3. Table C-62 shows the key streamflow stations selected for use in this analysis. These stations cover a total drainage area of 9,763 square miles, with an average local drainage area of about 514 square miles. Schematic diagrams of the stations showing relative locations and incremental or local areas are shown in Figure C-38.

Generation of hypothetical streamflows, as described in Chapter 3, was also accomplished using the key stations. A summary of the maximum and minimum occurrences for the recorded and reconstituted flows and for all 10 periods of generated flows for the specified durations are shown in Table C-63.

TABLE C-62
KEY STREAMFLOW STATIONS
SUB-REGION D

Analysis Group	NAR Number	Station	Station Name	Drainage Area (Sq.Mi.)	Approx. Yrs. of Observed Record
I	451		W. Br. Delaware R. at Hale Eddy,N.Y.	593	54
I	452		E. Br. Delaware R. at Fishs Eddy,N.Y.	783	55
I	453		Delaware R. nr. Barryville,N.Y.	2,023	26
I,II,II	454		Delaware R. at Pt. Jervis,N.Y.	3,076	63
I,IV	455		Delaware R. at Montague,N.Y.	3,480	28
I,IV	406		Bush Kill at Shoemakers,Pa.	117	59
II,IV	457		Delaware R. at Belvidere,N.J.	4,535	45
II,IV	408		Lehigh R. at Bethlehem,Pa.	1,279	62
I,II,III,IV	459		Delaware R. at Trenton,N.J.	6,780	55
II	410		Schuylkill R. at Pottstown,Pa.	1,147	41
II	461		Perkiomen Cr. at Graterford,Pa.	279	53
II,IV	462		Schuylkill R. at Philadelphia,Pa.	1,893	36
III	413		N. Br. Rancocos Cr. at Pemberton,N.J.	111	46
III	414		Brandywine Cr. at Chadds Ford,Pa.	287	56
III	415		Maurice R. at Norma,N.J.	113	35
III	416		Toms R. nr Toms River,N.J.	124	39
III	417		N. Br. Raritan R. Nr. Raritan,N.J.	190	44
III	418		S. Br. Raritan R. at Stanton,N.J.	147	50
III	419		Ramapo R. nr. Mahwah,N.J.	118	48
III	420		Passaic R. at Little Falls,N.J.	762	70



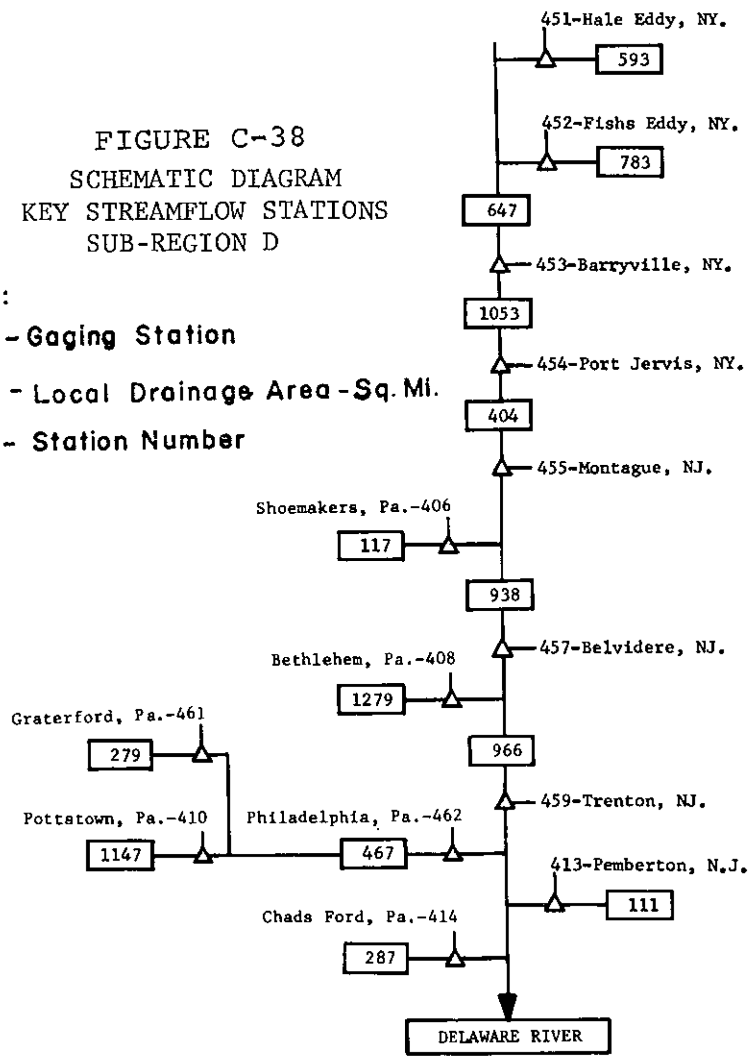


FIGURE C-38
SCHEMATIC DIAGRAM
KEY STREAMFLOW STATIONS
SUB-REGION D

LEGEND:

△ - Gaging Station

$\boxed{123}$ - Local Drainage Area - Sq. Mi.

156 - Station Number

TABLE C-63
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION D
(Cubic feet per second)

Sta. No.			1 Month		6 Months		54 Months	
			Max.	Min.	Max.	Min.	Max.	Min.
410		Hist.	8,947	200	24,974	2,105	131,933	61,359
	Gen.	High	16,803	207	40,065	2,663	160,342	76,136
		Low	9,143	77	26,142	1,676	125,455	61,625
461		Hist.	2,193	8	5,821	212	28,016	11,669
	Gen.	High	4,480	13	9,201	274	40,638	14,407
		Low	2,215	6	6,202	140	27,541	11,987
462		Hist.	13,585	286	37,795	3,069	202,754	91,315
	Gen.	High	35,052	285	62,375	3,766	241,775	118,479
		Low	13,819	80	40,708	2,449	199,527	95,992
413		Hist.	500	37	2,043	324	11,545	6,713
	Gen.	High	921	35	3,038	352	13,805	6,938
		Low	542	15	2,134	240	11,433	6,256
414		Hist.	1,573	59	5,212	649	26,686	13,672
	Gen.	High	5,539	52	10,679	634	35,618	14,968
		Low	1,648	32	5,644	401	29,172	12,906
415		Hist.	750	35	2,084	294	11,770	5,638
	Gen.	High	2,331	32	4,000	341	14,503	6,841
		Low	537	17	2,151	212	11,862	6,081
416		Hist.	541	58	2,356	549	13,932	8,964
	Gen.	High	768	56	3,054	573	16,337	9,134
		Low	546	34	2,191	399	13,694	8,357

TABLE C-63 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION D

Sta. No.		1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
417	Hist.	1,272	14	4,440	260	21,441	9,413
	Gen. High	3,307	14	11,077	269	29,132	11,202
	Gen. Low	1,496	5	4,612	161	22,379	8,564
418	Hist.	1,057	15	3,470	279	17,210	7,106
	Gen. High	4,537	21	10,651	301	24,925	8,775
	Gen. Low	1,035	12	3,384	202	17,790	7,030
419	Hist.	1,151	8	3,593	203	18,163	7,545
	Gen. High	5,910	9	9,874	191	23,325	8,034
	Gen. Low	1,144	1	3,689	94	16,769	6,754
420	Hist.	6,755	26	20,607	688	92,259	23,810
	Gen. High	14,908	22	42,542	639	115,660	37,067
	Gen. Low	7,545	4	20,218	319	94,229	32,346
451	Hist.	5,416	25	13,287	491	70,733	34,521
	Gen. High	7,207	24	22,223	682	93,318	38,355
	Gen. Low	5,211	3	15,471	206	74,184	32,270
452	Hist.	10,499	61	20,735	804	104,498	53,344
	Gen. High	14,849	63	34,454	1,311	144,775	62,698
	Gen. Low	8,074	25	23,849	487	116,884	50,3247
453	Hist.	18,776	174	45,448	1,829	252,949	123,789
	Gen. High	41,784	164	87,065	2,986	347,039	147,900
	Gen. Low	19,899	70	53,403	1,430	273,404	121,387

TABLE C-63 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION D

Sta. No.			1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
454		Hist.	30,718	226	66,441	3,062	367,388	180,358
	Gen.	High	38,409	209	106,423	4,605	469,061	214,733
		Low	26,191	92	76,398	1,679	392,973	175,938
455		Hist.	33,007	321	80,667	3,217	435,198	204,753
	Gen.	High	58,498	281	168,446	5,399	570,776	249,581
		Low	31,793	164	94,695	2,490	456,789	207,846
406		Hist.	1,119	4	3,125	124	16,171	7,530
	Gen.	High	1,625	5	5,184	184	20,575	5,002
		Low	945	2	3,079	73	16,569	7,565
459		Hist.	63,195	957	149,090	10,365	812,924	377,397
	Gen.	High	75,889	967	249,453	14,251	990,573	477,212
		Low	54,423	391	159,449	6,442	817,677	403,815
457		Hist.	44,767	355	105,770	4,761	601,936	254,178
	Gen.	High	74,831	412	208,415	7,576	727,708	338,307
		Low	42,490	256	119,976	3,184	584,813	278,690
408		Hist.	11,920	308	30,392	3,061	169,302	82,385
	Gen.	High	20,998	266	47,937	3,821	188,060	97,797
		Low	10,514	96	31,919	2,419	157,887	80,420

Yield-Storage Relationships. Relationships between yield and storage in Sub-region D were derived by the methods described previously. Table C-64 summarizes the results in this Sub-region, giving the storage requirements for various demand rates and shortage criteria. A comparison of the results of using the historic record and synthetic traces at a shortage index of 0.01, shows that greater storage is required at the demand rates of 60% and 80% for the historic record. The difference is greatest in the central and lower reaches of the Delaware River. It should be noted that when the 1960's drought was excluded from the record, as shown in Chapter 3, for the Delaware River at Trenton, storage less than the synthetic requirements was obtained from the historic streamflows. At the lower demand rates, differences are comparatively small, and more homogeneity was obtained in both sets of curves. Figure C-39 shows the relationships between yield and storage for the Delaware River at Montague, N.J., in the graphic format adopted for use.

Minimum Flow. For purposes of plan formulation, Sub-region D was divided in three Areas and further into seven Sub-areas (Area 14 has no sub-areal divisions and is used in its entirety in this analysis).

The existing minimum flow for each Sub-area was derived by computing the monthly flow value from the historic record for a shortage index of 0.01. An adjustment, based upon the ratio of the mean seven-day flow during the dry season to the mean minimum monthly flow, was applied to obtain the seven-day low flows for each Sub-area. Where a gaging station did not concide with a Sub-area outlet, nearby gaging stations were used to estimate the low flow for the Sub-area concerned. Where recorded streamflows did not reflect the minimum flow which can be developed within a drainage area because of significant reservoir development and diversion from stream channels within an Area, such as is the case in Area 14, reservoir yields were determined using the methodology described in Chapter 3, and included with the minimum streamflow from the uncontrolled areas. Minimum flows do not include yield of reservoirs used for inter-Area diversion. Table C-65 lists the minimum flows derived for the Sub-areas in Sub-region D for a shortage index of 0.01.

As described in Chapter 3, adopted seven-day minimum flows are considered to have recurrence intervals of approximately 50 years. However, on the Delaware River, low flows are influenced greatly by releases from the New York City reservoirs necessary to satisfy Supreme Court decree requirements at Montague, N.J. These reservoirs control more than 25% of the 3,480 square miles of Sub-area 15a. The flow requirements at Montague have increased over the years as reservoirs have been placed in operation, but have been relaxed somewhat during extreme drought conditions. With Cannonsville Reservoir in operation, the design flow at Montague is now

TABLE C-64

STORAGE REQUIREMENT IN AF/SQ. MI. FOR INDICATED PERCENTAGES OF AVERAGE FLOW

SUBREGION D.

Station	D.A. SQ.MI.	AVERAGE FLOW.CFS.	S.I. = 0.0 HISTORIC 20%	40%	60%	80%	S.I. = 0.01 H 20%	S 20%	H 40%	S 40%	H 60%	S 60%	H 80%	S 80%	S.I. = 0.10 SYNTHETIC 20%	40%	60%	80%
W. Br. Del. R. @ Hale Eddy, N.Y.	593	1034	82	215	530	1170	62	78	170	195	460	430	1050	1150	39	135	300	800
E. Br. Del. R. @ Fishs Eddy, N.Y.	783	1618	90	260	450	1450	63	78	210	210	370	440	1300	1350	41	140	300	870
Del. R. nr. Barryville, Lcl.	647	1131	82	225	530	1300	63	60	190	190	480	375	1200	960	38	140	275	660
Delaware R. @ Port Jervis, Lcl.	1053	1671	66	170	360	1150	47	62	145	170	285	340	1100	1050	34	120	240	680
Delaware R. @ Montague, Lcl.	404	924	150	360	1000	2700	120	95	290	265	550	550	2600	2100	58	200	400	1250
Delaware R. @ Montague, N.J.	3480	6344	82	225	490	1350	60	57	180	190	400	375	1200	1100	27	125	270	700
Bushkill a Shoemakers, Pa.	117	232	94	230	430	1350	70	78	190	210	360	400	1250	1100	39	140	280	710
Delaware R. @ Belvidere, Lcl.	938	1542	78	200	610	1650	60	55	175	170	540	340	1550	1000	36	120	240	700
Lehigh R. @ Bethlehem, Pa.	1279	2282	-	115	300	850	-	-	80	86	230	220	780	620	-	50	150	420
Delaware R. @ Trenton, Lcl.	966	1451	49	185	660	1700	38	58	145	145	580	340	1550	910	36	100	210	550
Delaware R. @ Trenton	6780	12048	-	180	460	1300	-	-	140	135	390	290	1250	720	-	88	200	480
Schuylkill R. @ Pottstown, Pa.	1147	1836	24	125	430	1050	16	13	95	93	360	250	950	650	-	54	180	420
Perkiomen Cr. @ Graterford, Pa.	279	380	62	200	460	1050	49	45	170	160	400	310	1000	900	26	115	230	600
Schuylkill R. @ Phila., Lcl.	467	613	48	165	420	1100	30	34	130	110	375	270	1050	720	17	70	180	450
Schuylkill R. @ Phila.	1893	2826	21	130	420	960	15	-	105	95	360	230	940	640	-	58	150	420
N. Br. Rancocas Cr. @ Pemberton	111	170	-	57	190	580	-	-	33	35	140	140	470	520	-	-	65	300
Brandywine Cr. @ Chadds Ford, Pa.	287	384	-	60	170	650	-	-	43	62	140	215	580	720	-	21	110	460
Maurice R. @ Norma, N.J.	113	166	-	60	320	820	-	-	-	-	260	140	750	1100	-	-	64	370
Toms R. @ Toms River, N.J.	124	210	-	-	105	355	-	-	-	-	-	-	250	290	-	-	-	150
N. Br. Raritan R. nr. Raritan, N.J.	190	296	47	215	510	1150	33	36	135	145	440	420	1050	1200	-	90	260	820
S. Br. Raritan R. @ Stanton, N.J.	147	240	29	150	540	1450	23	23	105	115	480	370	1300	1200	-	64	210	700
Ramapo R. nr. Mahwah, N.J.	110	224	63	210	390	1150	43	60	260	200	340	510	1050	1650	21	125	310	1000

FIGURE C-39. SAMPLE YIELD-STORAGE CURVES - SUB-REGION D

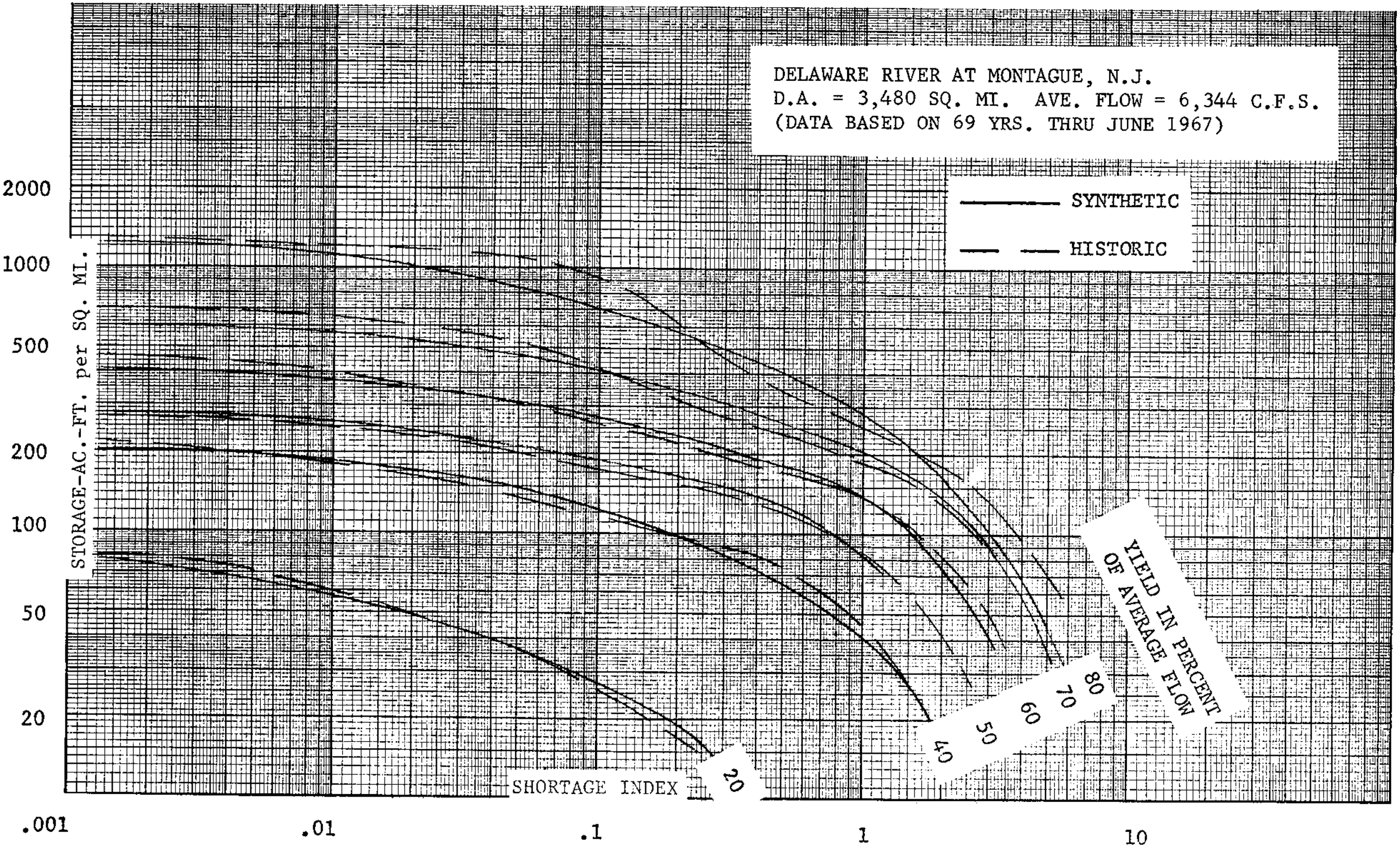


TABLE C-65

EXISTING MINIMUM STREAMFLOW - SUB-REGION D 1/

(Cubic feet per second)

	MONTHLY	7-DAY
AREA 14 2/	1,325	1,140
Sub-area 15a 3/	1,035	700 (1,750)
Sub-area 15b	1,255	630 (3,100)
Sub-area 15c	330	230
Sub-area 15d 4/	1,720	1,230
AREA 15	4,340	2,790 (6,310)
Sub-area 16a	360	290
Sub-area 16b	1,140	920
AREA 16	1,500	1,210
SUB-REGION D	7,165	4,730 (8,660)

1/ Figures in parentheses include allowance for the Tocks Island and Beltzville Projects (Sub-area 15b and assume a minimum flow of 1,750 c.f.s. is maintained at Montague, N.J.

2/ Does not include import from Area 15.

3/ Does not include 540 m.g.d. developed for export.

4/ Does not include import from Area 17.

1,750 c.f.s. During the recent drought, the minimum seven-day flow at Montague was about 565 c.f.s. in 1965.

As covered previously in the Sub-region C Summary, yield analysis of the New York City reservoir system under the criteria of the NAR Study, resulted in a maximum export from Area 15 of 540 m.g.d. This assumed that a minimum flow of 1,750 c.f.s. would be maintained at Montague.

For the purposes of supply analyses, the existing diversion from Area 15 to Area 14 via the Delaware and Raritan Canal was assumed to be 65 m.g.d. on the basis of 1965 records. Similarly, the import from Octoraro Creek in Area 17 was considered to be 25 m.g.d.

Minimum flow, reservoir yield and diversion data have been used in studies of existing and practical development resource covered in Appendix E and in connection with NAR Supply Model analyses.

SUB-REGION E

Sub-region E includes the Susquehanna River Basin, the drainage above the Potomac River along the west shore of Chesapeake Bay, and Chesapeake Bay and ocean drainage on the Delmarva Peninsula. It is the largest of the NAR Sub-regions, with a total drainage area of 35,655 square miles. Figure C-1 shows the Areas and Subarea divisions in the Sub-region.

Average annual precipitation is about 40 inches in the Susquehanna Basin (Area 17), and about 43 inches over Chesapeake Bay-Atlantic Ocean drainage (Area 18). More rainfall generally occurs during the spring and summer months than in the fall and winter. Maximum amounts are recorded in July and August, and the lowest amounts in February. Because of the differences in latitude and altitude within the Sub-region, annual snowfall ranges widely, from about 85 inches in New York State to some 8 inches in Virginia. The most frequent type of storm precipitation is the thunderstorm caused by atmospheric instability, affecting mostly local areas. Hurricanes cause heavy rainfall and are responsible for most of the short-term maximum precipitation in the Sub-region.

Average annual temperatures vary from about 59° F. in the south to about 45° F. in the northern part of the Sub-region. The prevailing winds are from the west and northwest at from 8 to 12 m.p.h. Average annual lake evaporation varies from about 27 inches in the north to about 38 inches in the south. Normal average evapotranspiration averages about 21 inches in Area 17 and 28 inches in Area 18.

The average annual runoff is approximately 18 inches, with about 50% occurring from March through May, and only 20% from June to October. Existing minimum seven-day flow is equivalent to about 0.1 c.s.m. Storage has little overall effect on streamflow, except for the weekly regulation pattern due to hydroelectric power generation on the lower main stem of the Susquehanna River. The Susquehanna River is subject to severe flooding, but, because of the extent of the basin, large portions may remain relatively unaffected by any individual storm. The Chesapeake Bay is particularly subject to hurricane caused flooding.

Overall, natural surface water quality is generally satisfactory. Dissolved solids concentrations are low to moderate, except in some mining areas, where high concentrations are found. The portion of the Coastal Plain Province, which lies in the southern portion of the Sub-region, is a highly productive source of ground water.

Chesapeake Bay, with a surface area of about 4,400 square miles, is the largest tidal estuary in the North Atlantic Region, and provides a valuable resource for culural and commercial use.

CLIMATE AND METEOROLOGY

Meteorologic Records

Sub-region E is represented by numerous climatological stations recording precipitation, snowfall, temperature and humidity. The principal source of this data is the National Weather Service. Figure C-40 shows the locations of selected meteorologic stations referred to in this Summary.

Precipitation

Average annual precipitation in Area 17 is approximately 40 inches. It is lowest in the northern portion of the Area and increases gradually to the south. Average annual precipitation in Area 18 is about 43 inches, varying from about 35 inches on the Atlantic Coast to 48 inches at Snow Hill, Md. (See Figure C-3.)

The season of maximum mean rainfall occurs during the months of July, August and September, with about 12 inches falling during this period. The months of April, May and June average about 11 inches, while the fall and winter months average about 9 inches each. The maximum months are July and August, each averaging 4.2 inches, and February has the lowest average, 2.5 inches. Table C-66 lists mean precipitation data for selected stations.

Average annual snowfall varies widely from a low of about 8 inches at Cheriton, Va., in Area 18 to a high of about 85 inches at Binghamton, N.Y., in Area 18. The norther and central portions of the Sub-region receive about 50 inches annually. In 1961, the maximum annual snowfall of 138 inches was recorded at Cortland, N.Y. Table C-67 shows average snowfall for selected stations.

The most frequent storm type occuring in Sub-region E is the thunderstorm, with 30 to 40 occurring each year. Thunderstorms are generally caused by local atmospheric instability, and usually affect only small areas within the Sub-region. Hailstorms and tornadoes occur much less frequently, about twice a year. Tornadoes are localized, of relatively short duration, and usually occur in sparsely settled areas.

Coastal storms and hurricanes affect the coastal area of Area 18. Hurricanes occasionally travel through the Sub-region, as Hurricane Connie did on August 11-13, 1955, causing heavy rainfall and flooding. These storms are responsible for most of the short-term maximum precipitation. The maximum 24-hour precipitation for the stations listed in Table C-66 is 7.67 inches, which occurred at Cortland, N.Y., on July 8, 1935, and at Emporium, Pa., on July 17, 1942.

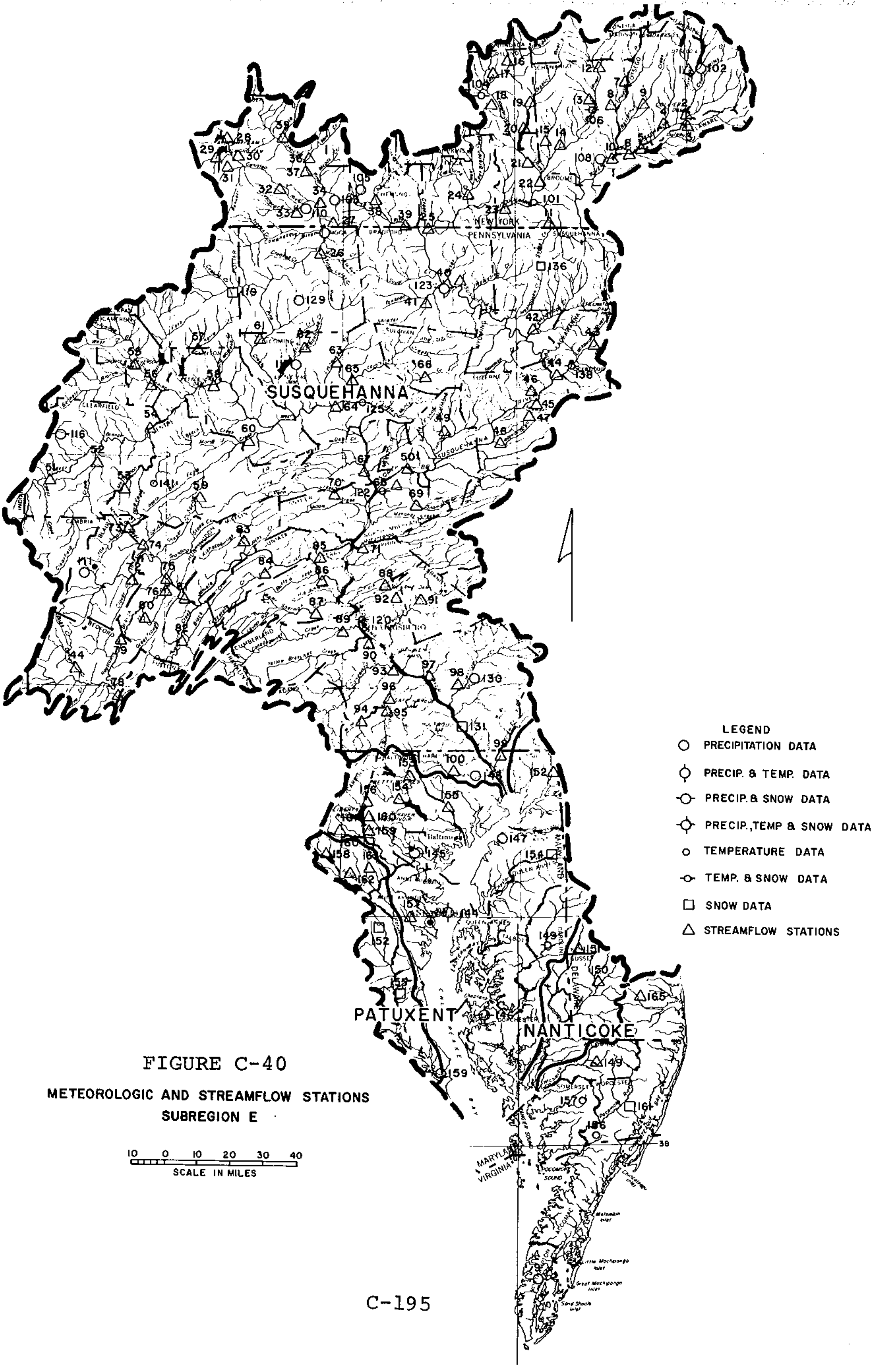


FIGURE C-40

METEOROLOGIC AND STREAMFLOW STATIONS
SUBREGION E

TABLE C-66

PRECIPITATION DATA(a) SUBREGION E(in inches)

Station	Map Code	Years of Record	Elevation ft.m.s.l.	Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Annual
Cooperstown,N.Y.	102	112	1240	Max	5.45	4.70	6.08	4.88		7.87	8.33	8.41	8.24	8.35	7.62	7.84	
				Min	.96	1.13	1.47	1.86	1.41	.93	1.45	1.18	.60	.20	1.13	.91	
				Mean(b)	2.96	2.74	3.22	3.33	3.93	3.77	4.27	3.98	3.70	3.49	3.32	3.07	40.70
Bainbridge,N.Y.	108	58	1015	Max	5.57	4.59	6.37	6.34	8.50	9.59	8.58	7.95	7.64	7.10	6.88	6.98	
				Min	0.73	1.18	1.25	1.72	0.67	1.44	0.68	0.38	0.50	0.41	1.13	0.94	
				Mean(b)	2.77	2.57	3.20	3.34	3.77	3.87	4.56	3.71	3.44	3.26	3.08	3.08	38.87
Elmira,N.Y.	105	86	863	Max	3.44	4.02	8.31	6.17	8.01	8.87	6.68	7.92	6.19	9.48	5.68	5.49	
				Min	0.64	0.46	0.91	1.27	0.70	1.00	0.76	0.50	0.41	0.13	0.34	0.40	
				Mean(b)	1.88	1.92	2.98	3.00	3.94	3.37	3.58	3.97	2.84	2.70	2.49	2.22	33.50
Wellesboro,Pa.	129	35	1920	Max	8.74	10.93	10.08	10.77	12.40	17.47	12.30	15.25	8.40	8.62	9.07	9.57	
				Min	0.72	0.21	0.24	0.57	0.57	0.61	0.96	0.25	0.20	0.03	0.50	0.36	
				Mean(b)	1.94	1.65	2.62	2.67	3.84	2.99	3.46	3.98	2.78	2.46	2.48	2.05	32.42
Towanda,Pa.	123	72	760	Max	4.99	4.89	6.99	6.55	8.81	8.46	8.98	8.87	8.31	7.54	5.47	6.00	
				Min	0.48	0.44	0.59	0.87	0.85	0.83	1.01	0.87	0.36	0.08	0.46	0.32	
				Mean(b)	1.86	1.93	2.86	3.09	4.02	3.18	3.84	3.33	3.99	2.95	2.62	2.17	34.34
Scranton,Pa.	138	65	746	Max	4.71	6.30	7.02	6.04	5.79	7.73	8.57	12.11	7.35	9.16	5.64	5.64	
				Min	0.57	0.92	0.77	0.97	0.90	1.02	0.79	0.67	0.91	0.08	0.75	0.49	
				Mean(b)	2.24	2.12	2.88	3.43	3.62	3.73	4.81	3.86	3.03	2.98	3.01	2.44	36.95
Sunbury, Pa.	122	78	480	Max	6.99	5.06	7.05	5.90	11.80	6.51	7.51	10.79	11.75	8.77	7.36	5.68	
				Min	0.58	0.00	1.32	0.86	1.17	0.31	0.85	0.29	0.57	0.03	0.44	0.31	
				Mean(b)	3.04	2.58	3.62	3.65	4.60	3.45	3.85	3.86	3.27	3.23	3.36	3.22	41.13
Altoona,Pa.	111	82	1500	Max	6.48	5.18	9.50	8.50	9.95	10.59	9.36	8.36	6.65	9.39	7.78	6.56	
				Min	0.52	0.17	0.44	1.10	1.80	1.50	1.01	0.92	0.61	0.10	0.27	0.39	
				Mean(b)	3.23	2.47	4.27	4.20	4.47	4.57	4.54	3.72	3.06	3.21	3.06	3.03	39.73
Lancaster,Pa	130	75	255	Max	5.92	5.66	6.61	8.35	9.42	7.98	9.66	13.94	10.07	8.39	9.02	7.46	
				Min	0.47	0.58	0.50	0.63	0.50	0.35	0.60	0.56	0.18	0.00	0.58	0.16	
				Mean(b)	2.89	2.48	3.61	3.60	3.90	3.90	4.89	4.94	3.51	3.22	3.16	2.99	40.98
Aberdeen,Md	143	39	62	Max(c)	7.00	5.60	6.70	7.24	7.18	6.37	9.45	12.86	8.53	6.27	9.12	5.60	
				Min(c)	6.60	0.53	0.84	0.77	1.56	0.15	0.33	0.38	0.09	0.05	0.33	0.21	
				Mean(c)	3.18	2.76	3.46	3.35	3.59	3.49	3.96	4.51	3.27	2.58	3.01	2.76	39.92
Coleman,Md	147	68	78	Max	7.52	8.85	7.53	7.71	10.73	8.11	11.24	13.57	8.54	6.90	8.45	7.42	
				Min	0.56	0.79	1.08	0.80	0.67	0.28	0.29	0.27	0.27	0.05	0.45	0.35	
				Mean(b)	3.61	2.93	3.86	3.43	4.17	3.64	4.29	4.97	3.71	3.08	3.41	3.18	44.28
Baltimore W.B. City,Md	145	95	114	Max	6.81	7.07	7.94	8.70	7.26	9.36	11.50	17.69	12.41	7.75	6.92	7.10	
				Min	0.33	0.65	0.46	0.88	0.61	0.37	0.35	0.30	0.09	0.05	0.44	0.15	
				Mean(b)	3.43	2.89	3.82	3.60	3.98	3.29	4.22	5.19	3.33	3.18	3.13	2.99	43.05
Annapolis USN Academy, Md.	144	94	55	Max	7.55	7.48	10.25	9.36	8.14	8.89	11.84	14.55	11.47	8.41	6.19	7.80	
				Min	0.32	0.54	0.63	0.28	0.73	0.81	1.03	0.19	0.08	0.09	0.46	0.26	
				Mean(b)	3.14	2.57	3.62	3.31	3.83	3.51	4.14	4.50	3.46	2.63	2.78	2.85	40.34
Solomons,Md	159	74	20	Max	8.96	6.44	6.70	6.92	8.55	7.03	17.44	11.83	13.37	6.38	7.20	6.26	
				Min	0.74	0.37	0.65	0.58	0.47	0.54	0.62	0.42	0.02	T	0.36	0.46	
				Mean(b)	3.55	2.78	3.61	3.50	3.76	3.45	5.57	5.00	3.49	3.11	3.33	2.97	44.22
Cambridge,Md	146	70	5	Max	8.43	7.19	9.08	8.39	8.48	8.09	11.78	17.34	16.26	9.55	7.32	6.30	
				Min	0.94	0.40	0.90	0.65	0.36	0.64	0.85	0.25	0.21	0.05	0.44	0.61	
				Mean(b)	3.55	3.24	3.90	3.63	3.63	3.65	4.52	5.00	3.51	3.21	3.66	3.22	44.72
Cheriton, Va.	9	38	11	Max	8.63	6.17	6.39	5.37	6.60	7.66	12.15	12.33	9.97	7.04	6.98	6.83	
				Min	1.48	1.02	1.07	0.43	0.42	0.29	0.80	0.15	0.44	0.36	0.45	0.64	
				Mean	3.37	3.63	3.77	3.08	3.06	3.44	4.68	4.20	4.00	3.26	3.22	2.95	42.59

(a) Based on years of record through 1965 except as otherwise noted.
(b) Data based on period 1931-1960.
(c) Data based on years of record through 1957.

TABLE C-67

SNOW DATA - SUBREGION E

Station	Map Code	Years of Record (a)	Elevation ft.,m.s.l.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
				Average Snowfall in Inches												
Cortland,N.Y.	104	60	1129	15.0	15.1	12.5	3.9	0.3	0	0	0	0	0.4	5.5	12.3	65.0
Norwich,N.Y.	106	50	1030	18.6	17.6	13.2	3.1	0.1	0	0	0	0	0.5	5.3	13.6	72.0
Montrose,Pa.	136	50	1560	14.1	16.0	15.7	4.5	0.1	0	0	0	0	0.4	5.2	11.7	67.7
Towanda,Pa.	123	64	760	9.2	10.4	9.1	2.9	0	0	0	0	0	0.1	3.0	7.5	42.2
Lawrenceville,Pa.	133	59	1000	11.2	10.8	8.7	2.5	0.1	0	0	0	0	0.2	2.6	8.6	44.7
Galeton,Pa.	119	28	1325	11.5	11.3	13.0	3.1	0	0	0	0	0	0.2	5.1	11.6	55.8
DuBois,Pa.	116	22	1670	12.5	12.2	12.2	3.1	0.1	0	0	0	0	0.3	6.6	12.9	59.9
Williamsport,Pa.	125	16	527	7.9	8.9	9.0	0.9	0	0	0	0	0	0	3.2	8.9	38.8
Scranton,Pa.(W.B.)AP	138	20	746	7.7	7.0	8.2	1.4	0	0	0	0	0	0.1	2.4	6.5	33.3
Harrisburg North,Pa.	120	22	323	8.4	7.4	6.9	0.2	0	0	0	0	0	0.1	1.8	6.4	31.2
Holtwood,Pa.	131	27	187	6.5	7.7	7.4	0.2	0	0	0	0	0	0.1	1.6	5.0	28.5
Woodstock,Md.	160	68	415	6.1	6.1	4.4	0.5	T	0	0	0	0	0.1	0.6	3.9	21.7
Baltimore,Md (W.B.) City	145	72	114	5.9	6.2	4.7	0.6	T	T	0	0	0	0.1	0.7	3.8	22.0
Millington,Md.	154	60	27	5.9	6.1	3.5	0.6	T	0	0	0	0	0.1	0.5	4.0	20.7
Annapolis,Md.USN Academy	144	64	55	5.8	5.8	3.4	0.3	0	0	0	0	0	0.1	0.6	3.2	19.2
Glen Dale Bell,Md.	152	40	151	5.8	5.9	4.2	0.3	T	0	0	0	0	0.1	0.6	3.6	20.5
Owings Ferry Landing,Md.	155	44	120	5.3	4.2	2.6	0.2	T	0	0	0	0	T	0.6	2.6	15.5
Denton,Md.	149	65	20	5.5	5.7	1.9	0.1	0	0	0	0	0	T	0.3	3.3	16.8
Cambridge,Md.	146	58	5	4.8	4.2	2.7	0.2	0	0	0	0	0	0.1	0.3	3.2	15.5
Snow Hill,Md.	161	26	14	3.4	3.2	2.9	0.1	T	0	0	0	0	T	0.1	2.3	12.0
Cheriton,Va.	9	28	11	3.6	1.8	1.4	0	0	0	0	0	0	0	0	1.5	8.3

(a) Number of full years of record through 1960 used in computing mean values.

A period of sub-normal precipitation in 1930-31 averaged from 60% to 70% of normal throughout most of the Sub-region. Precipitation during the 59-month period from October 1961 to August 1966 was about 75% of average, and departures of more than 50 inches were accumulated in places. These two droughts are generally considered the most severe on record.

Temperature

Table C-68 lists temperature data for selected stations in Sub-region E. As indicated in the Table, mean annual temperatures vary from about 59° F., in Md., to about 45° F. in N.Y. The extremes range from a low of -39° F. at Lawrenceville, Pa., to a high of 109° F. at several locations. January and February are the coldest months, with mean monthly temperatures ranging from 22° F. in the northern part of Area 17 to 40° F. in the southern part of Area 18. Maximum mean monthly temperatures occur during July, and have ranged from more than 78° F. at Phillipsburg, Pa., to about 88° F. at Glen Dale Bell, Md.

Temperatures exceeding 90° F. occur on about 3 or 4 days of the year throughout most of the Susquehanna River Basin, and on approximately 10 days south of Marietta, Pa. Temperatures averaging below 32° F. during the day occur for about 20 to 35 days per year, and readings of 0° F. and below are recorded on from one to 10 days per year. Figure C-2 (p. C- 6) shows the NAR's mean annual temperatures.

Humidity

Mean relative humidity averages about 70% in Area 17 and from 75% to 80% in Area 18. The averages for both January and July are about the same as the annual average; however, fairly wide seasonal differences exist in the diurnal fluctuations. At Harrisburg, Pa., which has an average of 81% at 1 a.m. and 50% at 1 p.m. in July, the respective January averages are 71% and 60%. Mean dew point temperatures are between 15° F. and 30° F., north to south, and between 60° F. and 67° F. in January. The average annual dew point temperature at Baltimore, Md., is about 44° F.

Wind

The prevailing January wind direction in Area 17 is from the west, and from the northwest in Area 18. In July, the prevailing winds are primarily from the southwest in both areas. The average velocity ranges from 8 m.p.h. inland to 12 m.p.h. along the Bay and the coastline. Maximum wind speeds of approximately 80 m.p.h. have occurred during blizzards and hurricanes.

TABLE C-68

TEMPERATURE DATA (a) -SUBREGION E(in degrees Fahrenheit)

Station	Map Code	Years of Record	Elevation ft. m.s.l.	Item	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		66		Mean Max	54.7	30.4	30.7	40.0	53.4	65.9	74.5	78.7	76.4	69.6	58.6	44.7	33.4
Coopertown,N.Y.	102	65	1240	Mean Min	34.7	12.7	11.7	20.9	32.8	42.9	52.1	56.5	54.8	48.1	38.0	28.7	17.6
		30		Mean	45.7	22.7	23.0	31.0	44.1	55.3	64.4	68.7	66.6	59.7	49.4	38.0	25.7
		68		Mean Max	56.1	30.9	31.1	40.5	54.2	66.7	77.1	80.9	79.0	72.2	61.3	46.0	33.7
Cortland,N.Y.	104	67	1129	Mean Min	36.8	15.8	14.9	23.2	34.5	44.3	53.3	57.8	56.1	50.2	40.7	31.0	20.0
		30		Mean	46.5	23.7	23.5	31.3	44.3	55.8	65.2	70.1	68.1	60.6	50.3	38.6	26.7
		70		Mean Max	57.5	33.2	33.4	42.8	56.0	68.1	77.4	81.9	79.7	73.1	61.2	47.4	35.8
Binghamton,N.Y.	101	70	858	Mean Min	38.2	17.9	16.4	25.2	36.1	46.3	55.1	59.8	57.8	51.1	40.7	32.0	20.9
		30		Mean	48.8	26.6	26.4	34.4	46.9	58.2	67.3	71.8	69.8	62.5	51.9	40.6	29.3
		63		Mean Max	59.9	35.0	36.2	45.6	58.9	71.2	80.0	84.2	81.9	75.2	63.8	49.1	37.1
Lawrenceville,Pa	133	63	1000	Mean Min	35.5	15.6	14.5	23.2	33.2	43.2	52.2	56.5	54.6	48.0	37.5	28.9	19.1
		30		Mean	48.0	26.1	26.2	33.9	46.4	57.6	66.7	70.6	68.6	61.7	51.0	39.0	28.2
		66		Mean Max	59.1	35.0	35.6	45.2	58.4	70.1	78.3	83.1	80.4	74.6	63.0	48.6	37.5
Towanda,Pa	123	66	745	Mean Min	37.6	17.5	16.8	25.4	35.4	45.6	53.9	58.5	56.5	50.1	39.7	30.8	20.7
		30		Mean	49.0	27.4	27.6	35.4	47.5	58.3	67.0	71.3	69.5	62.5	51.8	40.6	29.5
		16		Mean Max	60.7	35.8	38.2	47.4	61.2	71.1	80.3	84.9	82.7	74.9	65.0	49.6	37.8
Williamsport,Pa	125	16	527	Mean Min	40.3	20.6	21.5	28.1	31.9	47.7	56.7	61.1	59.5	52.6	41.9	32.2	22.2
		16		Mean	50.7	28.8	29.2	37.4	49.4	60.4	69.2	73.6	71.6	64.1	53.1	41.1	30.4
		18		Mean Max	55.9	32.6	34.5	42.0	56.1	67.2	74.8	78.5	77.0	69.8	60.0	45.1	33.5
Philipsburg,Pa	141	18	1980	Mean Min	34.6	16.2	16.4	22.5	33.5	42.8	50.3	53.5	51.9	45.3	36.7	27.7	17.9
		18		Mean(b)	45.3	24.4	25.5	32.3	44.8	55.0	62.5	66.0	64.5	57.5	48.4	36.4	25.7
		88		Mean Max	64.2	42.2	43.4	51.6	62.9	73.8	82.2	86.4	84.0	77.8	66.9	54.7	44.4
Baltimore-	145	88	114	Mean Min	48.2	28.4	28.9	35.5	45.2	55.9	64.8	69.7	67.9	61.4	50.2	39.8	31.1
W B City, Md		30		Mean	57.6	37.3	37.8	44.7	55.7	66.1	74.7	79.1	77.3	70.6	60.0	48.8	39.0
		65		Mean Max	64.0	42.5	42.8	52.1	62.6	73.1	81.4	85.6	83.6	77.9	67.2	55.3	44.4
Annapolis-	144	65	55	Mean Min	48.1	28.0	27.6	35.5	45.0	55.5	64.6	69.3	68.2	62.4	50.9	40.0	30.7
USN Academy,MD		30		Mean	56.3	36.1	36.4	43.1	53.8	64.1	73.2	77.5	76.0	69.9	59.2	48.1	38.1
		60		Mean Max	66.2	44.3	45.0	54.2	65.4	75.7	83.7	87.5	85.5	80.0	69.3	57.4	45.8
Denton,Md	149	60	20	Mean Min	45.0	26.5	26.2	33.7	42.2	52.1	61.0	66.0	63.8	57.5	46.1	36.5	27.8
		64		Mean	55.5	35.4	35.5	43.9	53.7	63.9	72.3	76.6	74.7	68.8	57.7	46.8	36.8
		60		Mean Max	66.6	44.9	46.2	54.6	65.9	76.2	83.7	87.8	85.6	80.2	69.4	57.5	46.9
Cambridge,Md	146	60	5	Mean Min	46.8	28.1	28.1	35.0	44.2	53.9	62.6	67.5	65.8	59.6	48.8	38.5	30.0
		64		Mean	56.6	36.4	36.7	44.7	54.8	65.0	73.2	77.6	75.8	70.0	59.1	47.9	38.3
		62		Mean Max	66.1	46.2	46.7	55.2	65.1	74.4	81.5	85.6	83.8	79.2	69.3	58.1	48.0
Princess Anne,	157	62	15	Mean Min	44.9	27.0	27.0	33.9	42.0	51.6	60.6	65.9	64.3	57.4	45.6	35.6	28.2
Md.		81		Mean	56.0	37.1	37.6	45.1	54.2	63.3	71.5	76.1	74.5	68.7	57.7	47.4	38.8
		34		Mean Max	66.9	47.5	47.2	55.3	65.5	75.5	82.5	86.8	84.9	79.6	69.7	59.1	49.5
Pocomoke City,Md.	156	34	20	Mean Min	47.6	29.8	28.8	35.9	44.6	54.4	62.8	68.4	66.7	60.1	49.5	39.0	30.9
		35		Mean	57.2	38.5	38.0	45.6	55.0	65.0	72.7	77.6	75.8	69.8	59.6	48.9	40.1

(a) Based on years of record thru 1960 as indicated in third colum except as otherwise noted
(b) Data based on years of record through 1965.

Evaporation

Mean annual lake evaporation increases from 27 inches in the north to 38 inches in the southern part of the Sub-region. From north to south, 70% to 76% of the evaporation occurs from May to October. The normal July evaporation from lakes and reservoirs is about 5 inches.

HYDROLOGY

Existing Resource

Hydrologic Records. Streamflows are currently measured at about 200 gaging stations in the Sub-region, with about 135 gages located in Area 17 and the remainder in Area 18. Published records include daily discharges summarized on a monthly and yearly basis. The U.S. Geological Survey has collected and published these records in cooperation with states, municipalities, and other interested Federal agencies. Selected stream gaging stations referred to in this Summary are located on Figure C-40.

Average Flow. Average streamflow over the Sub-region's 35,655 square miles of drainage area is about 47,000 c.f.s. This represents about 45% of the average annual precipitation. Runoff, on a per square mile basis, is the greatest in Sub-area 17b at 1.5 c.s.m., and the lowest in Sub-area 18a at 0.9 c.s.m., with a Sub-regional average of 1.3 c.s.m. Table C-69 shows estimated average runoff by Sub-area.

TABLE C-69
AVERAGE ANNUAL RUNOFF - SUB-REGION E
(Drainage area in square miles, average runoff in c.f.s.)

	DRAINAGE AREA	AVERAGE RUNOFF
Sub-area 17a	7,797	10,550
Sub-area 17b	5,682	8,800
Sub-area 17c	3,354	4,220
Sub-area 17d	7,267	10,500
Sub-area 17e	3,410	4,430
AREA 17	27,510	38,500
Sub-area 18a	2,705	2,550
Sub-area 18b	5,440	5,950
AREA 18	8,145	8,500
SUB-REGION E	35,655	47,000

Streamflow Variation. Maximum monthly flows have occurred, with very few exceptions, in March and April in the Susquehanna Basin, and usually in April and May in drainage basins on the western shore of Chesapeake Bay. High flows tend to occur somewhat earlier on the Eastern Shore. Maximum monthly flows are often five to six times average flows. Minimum monthly flows have occurred most frequently in September. However, many are recorded in October, and occasionally in November. Minimum flows are generally about 2% to 10% of average. Table C-70 shows average, maximum and minimum monthly flow data for selected stations.

Existing Regulation. Sub-region E has nearly 1.8 million acre-feet of existing storage, with almost 1.5 million acre-feet in Area 17 and the remainder in Area 18. Area 17 storage is operated mostly for municipal supply, with some having joint flood control and recreation use. Several low dams on the lower end of the Susquehanna river are operated for power purposes. Storage in Area 18 is located exclusively on the western shore and is operated for municipal supply with some conjunctive recreational use.

No attempt has been made to identify all diversions into or out of the Sub-region, however, some of more significant diversions follow:

The Delaware River Basin Commission has granted approval of a diversion of about 3 m.g.d. of water from Bear Creek in the Lehigh River Basin for water supply in the vicinity of Wilkes-Barre, Pa. Two export diversions from Area 17 exist in Chester County, Pa. -- one with an average rate of about 25 m.g.d. and the other with a rate of between 0.5 to 1 m.g.d. A large project is presently underway to divert water from the Susquehanna River to the City of Baltimore for public supply. The intake for this project is located about 1,000 feet upstream of Conowingo Dam and the design capacity is 250 m.g.d. A capacity of 150 m.g.d. is presently available. Also, the Aberdeen Proving Ground diverts about 2.5 m.g.d. from Deer Creek in the Susquehanna River Basin, which is discharged as waste into Chesapeake Bay.

Two export diversions exist in Area 18, one for the Patapsco River and another from the Patuxent River. The smaller diversion, by the City of Westminster, Md., in Area 19, involves the import of about 1 m.g.d. from the Patapsco River. The other diversion involves the transfer of water from the Patuxent River by the Washington Suburban Sanitary Commission. This export, which averaged 44 m.g.d. in Water Year 1964 and 47 m.g.d. in Water Year 1965, is dependent upon the yields of Triadelphia and Rocky Gorge Reservoirs.

Quality and Suitability. Although natural fresh water quality in Sub-region E is generally satisfactory for most purposes, the

TABLE C-71

STREAMFLOW DATA (a) - SUBREGION E

Location	Map Code	D.A., sq.mi.	Years of Record	Average Flow-c.f.s.	Mean Monthly Flow-c.f.s. Maximum	Date	Minimum	Date	Structures Affecting Natural Streamflow
Oaks Cr. at Index, N.Y.	1	103	30	165	1,151	9/40	2.32	10/64	Canadarago Lake
Sus. R. at Colliers-ville, N.Y.	2	351	41	557	3,929	4/40	16.7	11/64	Otesego & Canadarago Lakes
Sus. R. at Unadilla, N.Y.	6	984	27	1,541	9,496	4/40	58.9	10/64	
Unadilla R. nr. New Berlin, N.Y.	7	196	41	320	1,670	3/36	14.2	9-10/64	
Unadilla R. at Rockdale, N.Y.	10	518	31	812	5,395	4/40	34.2	9/64	
Chenango R. at Greene, N.Y.	14	598	28	896	5,768	4/40	40.4	10/64	Some diversion
Shackham Brook nr. Truxton, N.Y.	16	3.1	32	5.38	37.3	4/40	.06	9/64	
Tioughnioga R. at Itasko, N.Y.	21	735	36	1,214	7,682	4/40	53.2	9/39	Whitney Point Res., since 3/42
Chenango R. nr. Chenango Forks, N.Y.	22	1,492	52	2,399	15,230	4/40	107 *	(9/39) (10/64)	Whitney Point Res.
Sus. R. at Conklin, N.Y.	11	2,240	52	3,562	21,340	4/40	130	10/64	
Owego Cr. nr. Owego, N.Y.	24	186	35	272	1,756	4/58	9.6	9/64	
Canisteo R. at Arkport, N.Y.	28	30.5	28	33.5	205	4/40	.86*	9/64	Arkport reservoir, since 11/39
Canisteo R. at W. Cameron, N.Y.	32	342	29	342	2,280	4/40	20.3	8/39	Arkport & Almond Res.
Tioga R. at Lindley, N.Y.	27	770	35	781	7,157	3/36	13.1	9/64	
Tioga R. nr. Erwins, N.Y.	34	1,370	47	1,341	11,350	3/36	39.8	9/64	
Cohocton R. nr. Camp-bell, N.Y.	37	472	47	440	3,793	3/36	27.8	9/65	Diversion
Chemung R. at Chemung, N.Y.	39	2,530	59	2,474	20,910	3/36	97.3	9/32	
Towanda Cr. nr. Monroeton, Pa.	41	215	51	283	2,287	3/36	1.76	9/64	
Sus. R. at Towanda, Pa.	40	7,797	52	10,380	66,750	4/40	279	10/15	
Tunkhannock R. at Dixon, Pa.	42	383	51	531	2,910	3/36	12.4	9/64	
Sus. R. at Wilkes Barre, Pa.	45	9,960	66	13,080	85,900	4/40	637	9/64	
Wapwallopen Cr. nr. Wapwallopen, Pa.	48	43.8	46	63	623	11/52	4.04	9/64	
Sus. R. at Danville, Pa.	50	11,200	66	15,100	97,110	4/40	740	9/64	
W. Br. Sus. R. at Bower, Pa.	51	315	52	544	3,369	3/36	28.7	10/63	
Clearfield Cr. at Dimeling, Pa.	52	371	52	565	4,153	3/36	16.9	10/30	Glendale Lake, since 12/60
Driftw'd Br. Sinnamahoning Cr. at Stlg Run, Pa.	55	272	52	446	3,366	3/36	5.16	9/64	
Sinnamahoning Cr. at Sinn., Pa.	56	685	27	1,093	5,608	3/45	29.8	9/64	
W. Branch Sus. R. at Renova, Pa.	58	2,975	58	4,874	34,360	3/36	139	10/30	Several reservoirs
N. Bald Eagle Cr. at Beech Cr. Sta., Pa.	60	559	55	780	4,958	3/36	107	11/30	
Pine Cr. at Cedar Run, Pa.	61	604	47	806	3,877	3/36	19.3	9/64	

TABLE C-71 CONT.

STREAMFLOW DATA (a) - SUBREGION E

Location	Map Code	D.A., sq.mi.	Years of Record	Average Flow-c.f.s.	Mean Monthly Flow-c.f.s. Maximum	Date	Minimum	Date	Structures Affecting Natural Streamflow
Lycoming Cr. nr. Trout Run, Pa.	63	173	51	273	1,788	3/36	6.25	9/64	
W. Br. Sus. R. at Williamsport, Pa.	64	5,682	70	8,745	62,970	3/36	408	11/30	Several reservoirs
Loyalsock Cr. at Loyalsock, Pa.	65	443	40	736	4,490	3/36	13.8	9/64	
W. Br. Sus. R. at Lewisburg, Pa.	67	6,847	26	10,340	56,360	4/40	589	9/64	Several reservoirs
Penn Cr. at Penns Cr., Pa.	70	301	36	411	3,093	3/36	34.1	11/30	
E. Manhantango Cr. nr. Dalmatia, Pa.	71	162	36	214	1,257	3/36	3.98	9/32	
Frankstown Br. Juniata R. at Wmsburg, Pa.	72	291	49	386	3,561	3/36	45.9	(10/30) (9/32)	
Little Juniata R. at Spruce Cr., Pa.	74	220	27	358	1,509	4/40	64.7	10/63	
Raystown Br. Juniata R. at Saxton, Pa.	79	756	54	889	7,669	3/36	57.6	9/63	
Juniata Cr. nr. Mapleton Depot, Pa.	81	2,030	28	2,357	9,845	4/40	245	10/63	
Tuscarora Cr. nr. Port Royal, Pa.	84	214	47 (thru'58)	259	2,347	3/36	6.53	9/30	
Juniata R. at Newport, Pa.	86	3,354	66	4,233	33,600	3/36	351	10/63	
Sherman Cr. at Shermansdale, Pa.	87	200	36	275	1,941	3/36	18.1	8/30	
Conodoquinet Cr. nr. Hogestown, Pa.	89	470	35 (thru'58)	567	3,210	3/36	53.4	11/30	
Sus. R. at Harrisburg, Pa.	90	24,100	75	34,000	216,000	3/36	2,066	9/64	
Swatara Cr. at Harper Tav., Pa.	91	337	46	558	2,990	3/20	15.9	9/32	
W. Conewago Cr. nr. Manchester, Pa.	93	510	37	557	3,450	3/36	9.71	10/41	Conewago Lake
W. Br. Codorus Cr. at Spring Grove, Pa.	94	74.3	35 (thru'64)	74.1	360	3/36	8.67	10/41	Diversion
S. Br. Codorus Cr. nr. York, Pa.	95	117	38	128	686	8/33	3.01	10/41	Reservoir, diversion
Sus. R. at Marietta, Pa.	97	25,990	34	35,390	229,100	3/36	2,296	9/64	
Conestoga Cr. at Lancaster, Pa.	98	324	35	376	1,765	3/36	36.3	8/57	Diversion
Deer Cr. at Rocks, Md.	100	94.4	38 (thru'64)	121	362	9/33	26	8/64	
Little Gunpowder Falls at Laurel Bk., Md.	155	36.1	37 (thru'63)	46.8	133	5/52	7.83	10/31	
Piney Run nr. Sykesville, Md.	161	11.4	27 (thru'58)	12.9	45.3	5/52	1.73	9/41	
Patuxent R. nr. Burtonville, Md.	162	127	31 (thru'44)	124	414	4/36	9.37	9/30	Triadelphia Res., 6/48. Diversion since 8/39.
Little Pat. R. at Guilford, Md.	163	38	31 (thru'63)	40.2	141	4/37	3.88	9/32	
North River nr. Annapolis, Md.	157	8.5	31 (thru'63)	10.6	27.3	8/55	2.55	9/32	
Nanticoke R. nr. Bridgeville, Del.	150	75.4	20 (thru'63)	93.2	376	2/61	10.1	9/43	
Beaverdam Cr. nr. Salisbury, Md.	149	19.5	28 (thru'63)	23.8	80.1	3/58	3.75	9/30	

Note: Stations are not necessarily listed in the usual downstream order. Refer to map code number sequences.

effects of acid mine drainage in Area 17 and salt water intrusion in Area 18 limit usefulness in some instances. It has been estimated that anthracite mining has resulted in degradation of quality on more than 1,200 miles of streams in the Susquehanna Basin.

Water throughout the Sub-region can be generally classed as the calcium-magnesium type, except for an area in the vicinity of the Nanticoke River in Maryland where the sodium-potassium type is more prevalent. Water is relatively soft in many areas, however, in the headwaters and some mid-basin portions of Area 17, moderate hardness occurs.

Sediment loads are moderate, except for the Baltimore, Md., and surrounding area north to the Pennsylvania border, where suspended sediment concentrations are significantly higher. The average annual sedimentation rate for the Sub-region is 115 tons per square mile. (See Appendix Q, Erosion and Sedimentation).

Industrial and non-industrial waste sources discharged about 2.7 million populations equivalents (PE) of biodegradables, as measured by biochemical oxygen demand (BOD), into the waters of the Sub-region. This represents about 47% of the organic waste load of Sub-region E. In addition, it has been estimated that more than 1 million pounds of acid per day are discharged into the waters of Area 17 from active and abandoned mining operations. (See Appendix L, Water Quality and Pollution).

Water quality problem areas include Baltimore, Annapolis, and the lower portions of major tributaries to Chesapeake Bay in Area 18, and numerous stretches of main stems and tributaries scattered throughout Area 17.

Floods. Because of the extent of the Susquehanna River Basin, very few flood events cover large portions of the Area, and certain tributaries may record stages relating to a rare flood event, while the main stem and other tributaries remain relatively unaffected. For instance, the northern section of the Susquehanna River in New York State experienced maximum flooding from successive storms in July 1935, while the Chemung River, a tributary flowing from the northwest, was not nearly so severely affected. Some of the more severe peak floods have occurred on one or more tributaries during the storms of May-June 1889, July 1935, March 1936, May 1942, August 1955 and March 1964.

The storm of March 1936 resulted in the greatest known flood in the basin. The peak discharge on the West Branch of the Susquehanna Basin at Williamsport, Pa., was 264,000 c.f.s., and the peak below Harrisburg, Pa., was 740,000 c.f.s. In comparison, the peak discharge at Harrisburg, during the storm of June 1889, was 654,000 c.f.s. Area 18 is more subject to hurricane flooding than

Area 17, and this type of storm is the cause of greatest damage along the shores of Chesapeake Bay. The storm of August 1933, although not a particularly intense hurricane, caused the maximum tide of record along the upper Bay. More intense storms, with respect to wind velocity, have passed through the area, but, because of their paths they did not cause the tidal extremes of the August 1933 storm. Table C-71 summarizes peak floods for selected stations in the Sub-region, and Table C-3 (p. C-17) contains peak frequency discharge information for selected locations.

Low Flow. The longest and most severe drought occurred in the early-1960s, affecting nearly all of Sub-region E. Periods of subnormal runoff were recorded for periods of as long as 50 months or longer at several locations. Another severe and prolonged period of deficient runoff occurred in 1930-31, when streamflow averaged about 64% of average annual runoff. For the 1960s drought, streamflow was about 75% of the long-term average; however, the carryover storage, from both ground and surface supplies, was more severely depleted during this drought because of its greater length. Other droughts of shorter duration occurred in 1914, 1941 and 1957.

Ground Water. The significance of the ground water resource in Sub-region E is illustrated by the fact that about one-fourth of the population of Area 17 derives its water supply from the ground. In the New York State portion of Area 17, it has been estimated that about 90% of the population obtains its supply from ground water.

Most of the ground water sources in the northern Appalachian Plateau are aquifers of glacially-deposited unconsolidated till and strata of sand, gravel and clay of glaciofluvial origin which are prevalent in river valleys. Sandstone and shale aquifers are used less frequently because of lower productivity and less natural quality. Glacial deposits, particularly stratified drift in the valleys of the northern parts of Area 17, yield moderate to large supplies of water -- up to about 1 m.g.d. Quality is generally good, however, wide variations are encountered.

The mountainous area south of the Appalachian Plateau, includes the Blue Ridge and Valley and Ridge Provinces. The Valley and Ridge Province contains productive aquifers in limestone and dolomites. However, this water is often hard because of its carbonate composition. Sandstones are also potentially good sources, yielding softer water with low mineral content. The Blue Ridge Province contains aquifers in crystalline rock. Supplies are generally small to moderate because of the impermeability of this rock. The Piedmont Province, further to the south, contains triassic besalts, limestones and metamorphic and igneous crystalline rocks. Yields are generally low, however, the quality is satisfactory, except for iron content, which is present in amounts larger than 0.3 p.p.m., in some places.

TABLE C-71

FLOOD DATA - SUBREGION E

Location	Map Code	Latest Data (W.Year)	Flood No. 1 Date	Flood No. 1 Peak Q. c.f.s.	Flood No. 1 Stage, ft.	Flood No. 1 $Q/(D.A.)^{.5}$	Flood No. 2 Date	Flood No. 2 Peak Q. c.f.s.	Flood No. 2 Stage, ft.	Flood No. 2 $Q/(D.A.)^{.5}$	Flood No. 3 Date	Flood No. 3 Peak Q. c.f.s.	Flood No. 3 Stage, ft.	Flood No. 3 $Q/(D.A.)^{.5}$
Oaks Cr. at Index, N.Y.	1	1965	1/22/59	2550	6.87	252	3/22/48	2500	6.60	247	4/ 4/60	2400	6.70	238
Sus. R. at Colliersville, N.Y.	2	1965	3/19/36	8740	8.13	467	4/ 5/60	7870	7.91	421	3/22/48	6980	7.48	378
Sus. R. at Unadilla, N.Y.	6	1965	12/30/42	21500	13.94	684	4/ 4/60	21200	14.25	675	9/22/38	21000	13.76	669
Unadilla R. nr. New Berlin, N.Y.	7	1965	3/ 5/64	6940	10.12	496	9/ 1/50	6600	9.95	471	3/18/36	6320	9.80	451
Unadilla R. at Rockdale, N.Y.	10	1965	12/31/42	17400	12.98	765	3/ 6/64	15200	12.30	668	3/ 1/40	13400	11.92	589
Chenango R. at Greene, N.Y.	14	1965	12/31/42	18900	18.33	772	3/ 6/64	16800	16.94	699	2/26/61	14700	15.92	602
Shackham Brook nr. Truxton, N.Y.	16	1965	6/ 3/47	487	-	276	6/24/40	416	4.45	236	10/23/37	360	4.43	203
Tioughnioga R. at Itoska, N.Y.	21	1965	7/ 8/35	61100	16.61	2260	3/18/36	28700	11.91	1059	2/26/61	22600	11.15	834
Chenango R. nr. Chenango Forks, N.Y.	22	1965	7/ 8/35	96000	20.30	2480	3/18/36	50100	15.26	1300	12/30/42	41000	14.00	1050
Sus. R. at Conklin, N.Y.	11	1965	3/18/36	61600	20.83	1300	3/22/48	60500	20.83	1280	3/28/13	52000	18.20	1100
Owego Cr. nr. Owego, N.Y.	24	1965	7/ 8/35	23500	10.50	1725	3/ 5/64	15500	11.14	1137	3/18/36	12200	9.00	895
Canisteo R. at Arkport, N.Y.	28	1965	7/ 8/35	4820	-	875	3/ 5/38	2000	3.91	363	2/20/39	2000	5.63	363
Canisteo R. at W. Cameron, N.Y.	32	1965	7/ 8/35	35000	-	1890	5/28/46	17600	18.09	952	3/ 7/56	15600	17.19	844
Tioga R. at Lindle , N.Y.	27	1965	5/28/46	75000	22.87	2710	10/14/55	50400	20.18	1820	11/26/50	48200	19.90	1740
Tioga R. nr. Erwins, N.Y.	34	1965	5/28/46	94000	23.54	254	11/26/50	58500	19.00	158	10/14/55	58500	19.00	158
Cohocton R. nr. Campbell, N.Y.	37	1965	7/ 8/35	41100	11.60	188	12/ 1/27	19700	8.90	905	3/12/36	16200	8.80	74.2
Chemung R. at Chemung, N.Y.	39	1965	5/28/46	132000	23.97	2620	3/ 6/64	93800	20.44	1860	10/15/55	89000	20.13	1770
Towanda Cr. nr. Monroeton, Pa.	41	1965	5/28/46	31300	12.53	2130	11/25/50	27400	11.77	1860	3/10/64	22200	10.77	1500
Sus. R. at Towanda, Pa.	40	1965	5/29/46	191000	25.08	2140	3/19/36	188000	25.03	2100	3/17/1865	188000	25.00	2100
Tunkhannock R. at Dixon, Pa.	42	1965	3/10/64	33600	14.26	1720	5/ 5/47	32200	13.96	1640	3/31/40	29400	13.50	1500
Sus. R. at Wilkes-Barre, Pa.	45	1965	3/20/36	232000	33.07	2320	3/18/1865	232000	33.10	2320	3/10/64	228000	32.80	2280
Wapwallopen Cr. nr. Wapwallopen, Pa.	48	1965	8/18/55	3140	9.23	475	7/22/52	2980	8.96	450	3/31/40	2840	8.84	430
Sus. R. at Danville, Pa.	50	1965	3/20/36	250000	27.40	2360	3/ 3/02	243000	26.90	2390	5/29/46	234000	25.98	2210
W. Br. Sus. R. at Bower, Pa.	51	1965	3/18/36	31500	19.74	1790	5/31/1889	27000	18.50	1580	3/10/64	15200	14.89	885
Clearfield Cr. at Dimeling, Pa.	52	1965	3/18/36	30600	18.49	1520	3/31/40	15400	14.23	800	3/10/64	13600	13.48	714
Driftw'd Br. Sinnamahoning Cr. at Stlg. Run, Pa.	55	1965	7/18/42	47800	15.00	2890	3/17/36	28400	12.00	1730	11/25/50	25800	10.65	1560
Sinnamahoning Cr. at Sinn., Pa.	56	1965	3/18/36	61200	21.94	2810	7/18/42	59800	21.58	2500	11/25/50	52200	19.66	2400
W. Branch Sus. R. at Renova, Pa.	58	1965	3/18/36	236000	29.39	4300	6/ 1/1889	211000	28.80	3840	5/21/1894	187000	23.00	3420
N. Bald Eagle Cr. at Beech Cr. Sta., Pa.	60	1965	3/18/36	25600	14.42	1080	6/17/16	22000	13.20	925	11/25/50	21400	11.39	3308
Pine Cr. at Cedar Run, Pa.	61	1965	5/28/46	52000	14.39	5567	11/25/50	33400	11.77	3377	3/18/36	30900	11.39	3308

TABLE C-71 CONT.

FLOOD DATA - SUBREGION E

Location	Map Code	Latest Data (W.Year)	Flood No. 1 Date	Flood No. 1 Peak Q. c.f.s.	Flood No. 1 Stage, ft.	Flood No. 1 $Q/(D.A.)^{.5}$	Flood No. 2 Date	Flood No. 2 Peak Q. c.f.s.	Flood No. 2 Stage, ft.	Flood No. 2 $Q/(D.A.)^{.5}$	Flood No. 3 Date	Flood No. 3 Peak Q. c.f.s.	Flood No. 3 Stage, ft.	Flood No. 3 $Q/(D.A.)^{.5}$
Lycoming Cr. nr. Trout Run, Pa.	63	1965	5/27/46	21800	19.37	1658	3/18/36	17000	17.34	1293	10/14/55	16800	16.40	1278
W. Br. Sus. R. at Williamsport, Pa.	64	1965	3/18/36	264000	33.57	3501	6/ 1/1889	252000	32.4	3342	5/28/46	223000	29.63	2958
Loyalsock Cr. at Loyalsock, Pa.	65	1965	11/16/29	51200	12.50	2432	11/26/50	51200	12.32	2432	8/24/33	50000	12.20	1425
W. Br. Sus. R. at Lewisburg, Pa.	67	1965	3/19/36	287000	32.10	3469	5/29/46	262000	28.43	3167	11/26/50	216000	26.05	2611
Penn. Cr. at Penns Cr., Pa.	70	1965	9/16/34	14900	13.00	859	3/18/36	12800	12.12	738	3/31/40	11700	11.61	674
E. Mahantango Cr. nr. Dalmatia, Pa.	71	1965	8/24/33	10600	13.66	833	11/25/50	9860	13.18	775	12/ 1/34	8940	13.00	702
Frankstown Br. Juniata R. at Wmsburg, Pa.	72	1965	3/18/36	47600	18.58	2204	6/ 1/1889	35500	19.10	2081	4/26/57	16600	13.90	973
Little Juniata R. at Spruce Cr., Pa.	74	1965	3/18/36	39800	19.10	2684	11/25/50	23100	15.77	1558	3/ 1/54	9600	11.53	647
Raystown Br. Juniata R. at Saxton, Pa.	79	1965	3/18/36	80500	24.54	2932	6/ 1/1889	71300	23.00	2583	4/27/37	31300	16.15	1140
Juniata Cr. nr. Mapleton Depot, Pa.	81	1965	6/ 1/1889	209000	35.90	4639	3/18/36	145000	38.20	3218	11/25/50	76800	26.40	1705
Tuscarora Cr. nr. Port Royal, Pa.	84	1958	11/25/50	19400	19.73	1327	3/18/36	14400	21.60	985	11/22/52	14100	16.79	964
Juniata R. at Newport, Pa.	86	1965	6/ 1/1889	209000	35.90	3603	3/19/36	190000	34.24	3275	3/ 1/02	118000	25.30	2034
Sherman Cr. at Sherman Dale, Pa.	87	1965	7/22/27	44000	20.34	3112	8/24/33	22300	14.05	1577	11/ 2/56	18300	12.75	1294
Conodoquinet Cr. nr. Hogestown, Pa.	89	1958	3/12/52	15700	12.16	724	12/ 2/34	13100	11.32	603	8/22/15	12500	12.91	576
Sus. R. at Harrisburg, Pa.	90	1965	3/19/36	740000	29.23	4774	6/ 2/1889	654000	26.80	4219	5/22/1894	613000	25.70	3955
Swatara Cr. at Harper Tav., Pa.	91	1965	6/ 1/1889	53000	25.6	2888	8/24/33	25300	17.53	1379	11/16/26	17800	14.60	970
W. Conewago Cr. nr. Manchester, Pa.	93	1960	8/24/33	47600	24.14	2106	11/ 9/43	25500	17.33	1128	9/17/34	24900	17.41	1102
W. Br. Codorus Cr. at Spring Grove, Pa.	94	1964	8/23/33	11200	11.82	1302	9/25/40	6190	8.85	720	9/16/34	6070	8.70	708
S. Br. Codorus Cr. nr. York, Pa.	95	1965	8/23/33	19300	17.97	1787	9/16/34	5920	10.09	548	11/ 9/43	5210	9.56	482
Sus. R. at Marietta, Pa.	97	1965	3/19/36	787000	60.73	4888	6/ 2/1889	630000	58.30	3913	5/29/46	492000	54.90	2435
Conestoga Cr. at Lancaster, Pa.	98	1965	8/24/33	22800	17.52	1267	5/23/42	17300	15.12	961	9/30/34	15000	14.04	833
Deer Cr. at Rock, Md.	100	1964	8/23/33	13600	17.70	1402	9/17/34	9900	15.90	927	11/16/26	9080	15.53	936
Little Gunpowder Falls at Laurel Bk., Md.	155	1964	8/23/33	9200	10.30	1530	6/14/28	8220	9.64	1370	11/16/26	7800	9.30	1300
Piney Run nr. Sykesville, Md.	161	1958	7/20/56	7380	12.00	2180	7/24/46	2100	6.95	620	8/23/33	1800	6.30	530
Patuxent R. nr. Burtonsville, Md.	162	1939(31 Jul)	8/24/33	11000	21.70	980	9/ 5/26	5480	15.27	490	6/19/28	5480	15.30	490
Little Pot. R. at Guilford, Md.	163	1964	9/ 1/52	5300	13.26	860	9/23/33	4210	12.50	680	7/18/45	3810	12.22	620
North River nr. Annapolis, Md.	157	1964	8/ 2/44	5000	6.22	1710	8/13/55	678	3.22	230	9/ 1/52	404	2.87	140
Nanticoke R. nr. Bridgeville, Del.	150	1964	8/26/58	2300	8.84	260	9/13/60	1620	8.08	190	1/ 7/62	985	6.99	110
Beaverdam Cr. nr. Salisbury, Md.	149	1964	8/23/33	Unknown	-	-	8/ 4/48	1480	14.31	340	8/ 9/59	733	12.12	170

Note: Stations are not necessarily listed in the usual downstream order. Refer to map code number sequences.

The Coastal Plain Province, covering most of Area 18, is a productive source of ground-water in Sub-Region E. The water is generally soft with low concentrations of dissolved solids, but there are areas of salt water encroachment and iron is a common constituent in places. Probably the most significant ground water quality problems in the Sub-region are high iron content and salinity. Many aquifers contain concentrations of iron in excess of .3 mg/l which is approximately equal to 0.3 p.p.m., and brackish water is encountered at times during heavy withdrawals following periods of low streamflow.

Estuaries and Coastal Areas. Chesapeake Bay is the largest tidal estuary in the North Atlantic Region. The shoreline is about 4,600 miles long with an average length of 200 miles and a width varying from 4 to 30 miles. The surface area of the Bay and its tributaries is about 4,400 square miles, with a mean depth of about 21 feet. The mean depth of the Bay proper is about 28 feet. The Bay receives water from a drainage area of about 65,000 square miles, with the Susquehanna River (Area 17) accounting for about 42% of the total.

The mean tidal range at Baltimore is about 1.1 feet. Ranges throughout the Bay vary between 2.5 and 0.7 feet. The following tabulation shows mean tidal ranges for various locations:

Location	Mean Range (ft.)
Pocomoke R. at Shelltown	2.4
Nanticoke R. at Roaring Pt.	2.3
Choptank River Light	1.4
Chester R. at Love Point	1.1
Susquehanna R. at Havre de Grace	1.7
Patuxent R. at Drum Point	1.2

The Chesapeake and Delaware Canal, which connects the Bay with the Delaware River Estuary, presently has a controlling depth of 27 feet and a width of 250 feet, except for a length of about 8 miles which has been deepened to 35 feet, and a 15-mile stretch which has been widened to 450 feet. These larger dimensions will eventually be extended along the total length of 17 miles.

Tidal variations cause a net outflow of fresh water (less than 3.6 p.p.m. salinity) from Chesapeake Bay to the Delaware Estuary.

Estimates of net outflow vary between 700 and 1,000 c.f.s. under the present dimensions to between 2,200 and 2,700 c.f.s. under the enlarged dimensions. Variations are probably due to lack of precise data on water movement in the Canal. This deficiency may be overcome with the completion of construction of a hydraulic model of the Bay by the Baltimore District of the Corps of Engineers. The model will help resolve questions that have been essentially unanswered to date, such as the nature of the salinity distribution and the effects that upstream impoundments and diversions have on this distribution, and the effects of channel geometry changes on physical and biological parameters. In addition to future modelling possibilities, more immediate investigations under the direction of the U.S. Army Engineers District, Philadelphia, are being conducted on the hydrographic and ecologic effects of enlargement of the Chesapeake and Delaware Canal by the Chesapeake Bay Institute of the Johns Hopkins University, the Chesapeake Biological Laboratory of the University of Maryland and the College of Marine Studies at the University of Delaware. The results will be utilized in guiding decisions about engineering the Canal's enlargement.

Water Availability Analyses

<u>Evapotranspiration</u>. The normal annual evapotranspiration for Sub-region E is about 24 inches, ranging from 21 inches in the northern part of Area 17 to about 28 inches in Area 18. This annual loss averages 46% of average annual precipitation in New York State and about 60% of average annual precipitation in the southernmost part of the Sub-region. Net evaporation water loss from reservoir surfaces is the evaporation which takes place over and above the evapotranspiration of the area which the reservoir replaces. In Area 17, the overall average annual evapotranspiration is about 25 inches. Assuming no change in ground water storage, and subtracting this quantity from the average evaporation rate of about 32 inches, leaves an average annual loss rate of about 7 inches. This figure can vary considerably depending upon individual site characteristics. There may, however, be net gains on a seasonal, or other short-term basis, due to the interception of precipitation directly on the reservoir surface instead of first seeping into the ground.

<u>Streamflow Simulation</u>. Estimation of missing monthly flows for the completion of streamflow records through 1967 at designated streamflow stations was accomplished, as described in Chapter 3. Through the use of the Hydrologic Engineering Center computer program on monthly streamflow simulation. Records were adjusted to a length of 77 years in Area 17, and 73 years in Area 18.

Table C-72 lists the key streamflow stations in the Sub-region selected for this purpose. The numeral at the left indicates the grouping in which the stations were combined for the correlation analyses. These stations cover a total drainage area of 26,103

TABLE C-72
KEY STREAMFLOW STATIONS
SUB-REGION E

Analysis Group	NAR Number	Station	Drainage Area (Sq. Mi.)	Approx. Yrs. of Observed Record
I	501	Susquehanna R. At Unadilla, N.Y.	984	28
I	502	Susquehanna R. at Conklin, N.Y.	2,240	54
I	553	Chanango R. nr Chenango Forks, N.Y.	1,490	54
I	504	Tioga R. at Lindley, N.Y.	770	36
I	505	Tioga R. nr Erwins, N.Y.	1,370	48
I	506	Chemung R. at Chemung, N.Y.	2,530	64
I	507	Susquehanna R. at Towanda, Pa.	7,797	53
I,III,IV	508	Susquehanna R. at Wilkes-Barre, Pa.	9,960	68
I,IV	509	Susquehanna R. at Danville, Pa.	11,220	68
II	510	West Br. Susquehanna R at Karthaus, Pa	1,462	27
II	511	Sinnemahoning Cr. at Sinnemahoning,Pa.	685	29
II	512	West Br. Susquehanna R. at Renovo, Pa.	2,975	60
II	513	Pine Creek at Cedar Rum, Pa.	604	49
II,IV	514	West Br. Susquehanna R.at Wms'port, Pa.	5,682	70
IV	515	West Br. Susquehanna R.at Lewisburg,Pa.	6,847	28
III	516	Raystown Br. Juniata R.at Saxton, Pa.	756	56
III	517	Juniata R. at Mapleton Depot, Pa.	2,030	30
III,IV	518	Juniata R. at Newport, Pa.	3,354	68
I,II,III,IV	519	Susquehanna R. at Harrisburg, Pa.	24,100	76
III	520	Susquehanna R. at Marietta, Pa.	25,990	35
III	521	Nanticoke R. nr Bridgeville, Del.	75	24
III	522	Little Patuxent R. at Guilford, Md.	38	35

FIGURE C-41

SCHEMATIC DIAGRAM

KEY STREAMFLOW STATIONS

SUB-REGION E

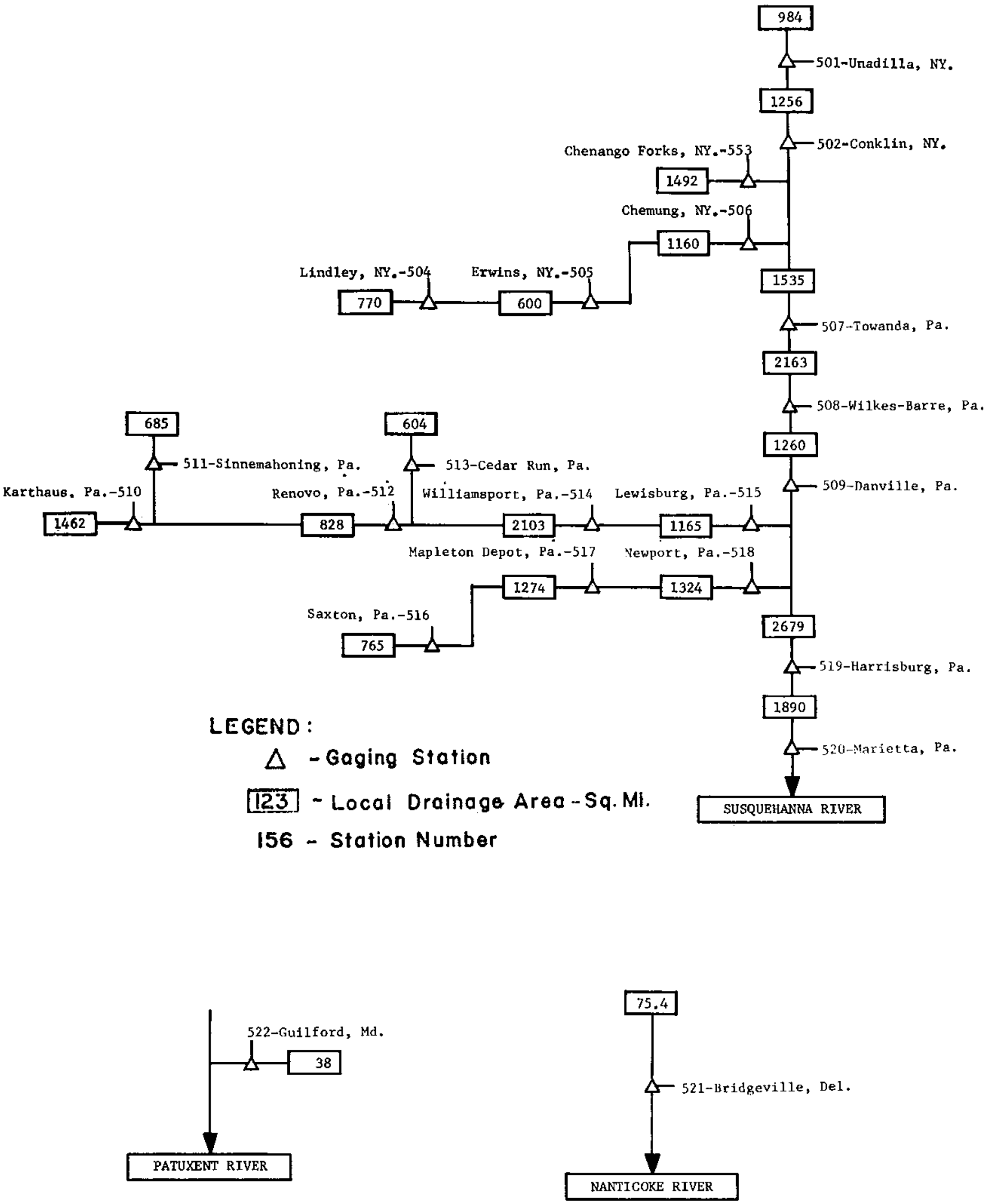


TABLE C-73
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION E
(Cubic feet per second)

Sta. No.			1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
519		Hist.	216,083	2,066	454,257	18,649	2,396,128	1,186,749
	Gen.	High	240,152	1,947	680,664	30,683	2,851,964	1,395,585
	Gen.	Low	171,465	679	494,245	14,138	2,325,682	1,114,943
508		Hist.	85,894	637	187,396	6,822	911,643	474,667
	Gen.	High	126,145	472	303,775	9,512	1,221,625	526,952
	Gen.	Low	78,849	140	211,491	2,756	926,921	431,730
506		Hist.	20,909	97	40,118	935	190,628	84,820
	Gen.	High	27,408	69	65,768	1,049	278,173	93,124
	Gen.	Low	16,032	20	44,290	343	194,090	78,488
507		Hist.	66,745	432	154,774	4,875	731,747	385,616
	Gen.	High	97,373	315	230,038	7,463	954,822	413,806
	Gen.	Low	62,647	90	165,357	1,989	756,292	340,074
501		Hist.	9,495	59	20,550	702	107,402	55,842
	Gen.	High	20,354	84	41,967	1,336	140,059	63,619
	Gen.	Low	7,950	27	23,749	385	112,796	54,487
502		Hist.	21,339	130	47,455	1,372	241,218	128,383
	Gen.	High	30,742	120	65,601	2,509	306,724	143,843
	Gen.	Low	18,440	35	58,863	674	251,133	121,518

TABLE C-73 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION E

Sta. No.			1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
514		Hist.	62,965	408	131,011	3,066	592,349	329,666
	Gen.	High	59,336	357	164,657	5,644	743,964	341,105
		Low	43,669	20	128,911	2,424	615,419	279,547
510		Hist.	12,716	138	35,617	1,244	168,286	84,079
	Gen.	High	28,108	96	49,436	1,738	211,424	95,168
		Low	11,963	58	35,060	1,090	169,295	77,494
511		Hist.	6,452	16	18,531	304	78,738	40,078
	Gen.	High	8,937	21	28,469	496	100,071	42,831
		Low	6,091	4	17,705	280	78,954	36,172
512		Hist.	34,358	139	74,395	1,164	346,076	170,898
	Gen.	High	39,112	122	107,319	2,514	432,365	192,746
		Low	27,078	9	77,971	1,029	363,955	158,459
513		Hist.	7,569	19	16,016	297	56,179	29,818
	Gen.	High	7,140	17	15,836	350	71,885	31,555
		Low	4,868	3	13,430	149	57,798	25,483
509		Hist.	97,103	740	201,484	8,082	1,087,011	541,639
	Gen.	High	142,179	476	287,462	12,498	1,066,557	617,789
		Low	81,031	94	225,456	3,498	1,184,236	505,497

TABLE C-73 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION E

Sta. No.			1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
505		Hist.	11,349	38	22,843	465	106,495	45,688
	Gen.	High	14,715	27	33,557	552	144,239	51,121
	Gen.	Low	9,245	5	24,801	155	104,443	41,525
516		Hist.	7,669	55	15,637	471	70,286	28,877
	Gen.	High	16,520	42	25,668	689	75,744	34,261
	Gen.	Low	5,477	4	14,369	436	62,986	23,364
517		Hist.	12,862	244	36,054	1,988	183,012	82,552
	Gen.	High	43,792	206	84,381	2,570	231,456	101,391
	Gen.	Low	12,635	74	38,530	1,839	170,247	80,340
518		Hist.	36,298	327	66,956	2,928	316,032	134,124
	Gen.	High	37,186	219	94,097	4,089	328,918	168,631
	Gen.	Low	22,803	80	65,916	2,266	290,337	142,033
520		Hist.	229,082	2,296	485,104	27,201	2,492,891	1,296,674
	Gen.	High	369,093	1,968	696,087	35,775	2,715,106	1,486,874
	Gen.	Low	170,710	1,202	510,067	21,051	2,472,718	1,207,369
521		Hist.	651	10	2,099	115	7,853	3,361
	Gen.	High	1,041	13	2,805	138	8,673	3,390
	Gen.	Low	617	7	1,772	99	6,447	3,025

TABLE C-73 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION E

Sta. No.		1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
	Hist.	65,131	601	156,330	6,515	724,387	380,204
515 Gen.	High	82,186	566	207,896	9,009	871,366	408,587
	Low	52,926	268	158,186	3,869	676,048	351,820
	Hist.	15,230	106	32,822	1,225	168,024	92,999
553 Gen.	High	22,460	74	50,822	1,824	215,816	95,221
	Low	13,224	23	36,392	626	170,177	84,104
	Hist.	7,157	13	12,529	206	62,634	26,573
504 Gen.	High	9,716	13	20,157	272	87,856	30,000
	Low	5,416	2	14,294	86	60,095	24,143
	Hist.	177	3	526	56	2,836	1,538
522 Gen.	High	383	4	832	64	3,217	1,685
	Low	163	2	616	43	2,828	1,374

square miles with an average local area of 1,300 square miles. Schematic diagrams of the stations showing relative location and incremental or local areas are shown in Figure C-41.

Along with the estimation of missing historic flows, the generation of synthetic streamflows was accomplished for 10, 100-year periods at the key stations.

Table C-73 shows a comparison of extreme volumes of historic (recorded and reconstituted) and synthetic flow, for periods of 1, 6 and 54 months. The synthetic data show the highest and lowest value obtained from any 100 year trace. For the maximum monthly volumes, the historic volume generally falls between the high and low generated values; however, the historic volume is usually greater than the high for the minimum month. It might be expected that more extreme occurrences would take place in 1,000 years of generated flow, which is the case here.

Yield-Storage Relationships. The relationships between yield and storage were derived by the methods discussed in Chapter 3. Storage routings were made for each series of historic and generated streamflow, using percentages of average flow as demand, and assuming varying amounts of storage in order to determine the storage index value previously described. This was done for each station listed in Table C-72. Table C-74 summarizes results in Sub-region E, giving a comparison between synthetic and historic storage requirements for selected demand rates. A sample of plotted results is shown by the curves in Figure C-42. Using the data on a per square mile basis, determinations of storage for a given demand rate drainage area and a desired shortage tolerance can be made for nearby ungaged locations, using caution not to use drainage areas which are too different from the area for which the curves were constructed.

Minimum Flow. For purposes of plan formulation, Sub-region E was divided into two Areas -- Area 17, which was further divided into five Sub-areas; and Area 18, with two Sub-areas. The existing minimum flow in each Sub-area was derived by computing the monthly flow value from the historic record for a shortage index of 0.01. An adjustment based on the ratio of the mean seven-day flow during the dry season to the mean minimum monthly flow was applied to obtain the seven-day low flows for each Sub-area. See Chapter 3 for a description of this methodology. Where a gaging station did not coincide with a Sub-area outlet, nearby gaging stations were used to estimate the low flow for the Sub-area concerned. Where recorded streamflows did not reflect available resources because of significant reservoir development with diversion above gages (within an Area), reservoir yields were determined separately and included with the minimum streamflow from the uncontrolled areas. Minimum flows do not include yield of reservoirs used for interbasin diversion. Table C-75 lists the existing minimum flows derived for Sub-region E (S.I. 0.01). As described in Chapter 3, adopted seven-day minimum flows are

TABLE C-76

STORAGE REQUIREMENT IN AF/SQ. MI. FOR INDICATED PERCENTAGES OF AVERAGE FLOW

SUBREGION E.

			S.I. = 0.0 HISTORIC				S.I. = 0.01								S.I. = 0.10 SYNTHETIC			
	D.A.	AVERAGE					H	S	H	S	H	S	H	S				
Station	SQ.MI.	FLOW.CFS.	20%	40%	60%	80%	20%	20%	40%	40%	60%	60%	80%	80%	20%	40%	60%	80%
Susquehanna R. @ Unadilla	984	1580	80	205	360	800	59	58	180	190	320	350	740	840	27	120	240	540
Susquehanna R. @ Conklin, Lcl.	1256	2010	-	230	420	840	-	-	210	210	375	390	760	900	-	140	260	650
Chenango R. nr. Chenango Forks	1492	2444	72	210	410	620	62	61	175	180	360	340	580	900	33	120	240	600
Tioga R. @ Lindley	770	806	66	145	360	770	52	55	140	155	305	400	710	900	37	115	250	640
Tioga R. nr. Erdwins,Lcl.	600	574	-	135	260	720	-	-	120	140	225	325	680	800	-	105	215	520
Chemung R. @ Chemung,Lcl.	1160	1168	45	145	340	690	39	44	125	130	290	350	620	730	30	100	240	540
Chemung R. @ Chemung	2530	2546	50	150	325	730	41	49	120	135	280	350	650	740	28	95	225	550
Susquehanna R. @ Wilkes Barre,Lcl.	2163	2686	-	140	350	890	-	-	115	-	300	300	820	730	-	80	200	540
Susquehanna R. @ Danville,Lcl.	1260	2090	-	235	720	3200	-	-	130	175	640	420	3100	1000	-	135	290	680
W. Br. Susquehanna R. abv. Karthaus	1462	2379	75	230	420	850	47	44	170	160	335	320	730	900	21	110	240	540
Sinnemahoning Cr. abv. Sinnemahoning	685	1122	90	255	450	760	76	80	220	205	380	400	680	1050	51	160	290	660
W. Br. Susquehanna R. Renovo,Lcl.	828	1470	145	325	520	1200	120	-	280	260	460	570	1100	1500	-	200	400	1000
Pine Cr. abv. Cedar Run	604	822	70	190	325	650	58	-	170	170	290	300	560	950	-	120	240	540
W. Br. Susquehanna R. abv. Williamsport,Lcl.	2103	3018	62	190	350	720	45	42	165	155	300	300	605	890	-	110	220	570
W. Br. Susquehanna Lewisburg,Lcl.	1165	1640	83	205	450	1100	64	52	160	140	380	290	1000	760	35	100	210	560
W. Br. Susquehanna R. Lewisburg	6847	10396	58	200	350	650	36	45	165	160	300	310	560	650	19	105	225	470
Raystown Br. Juniata R. @ Saxton	756	910	55	180	360	920	43	40	150	140	340	350	850	950	21	96	240	560
Juniata R. @ Mapleton Dpt,Lcl.	1274	1594	23	130	260	810	18	18	105	100	230	230	740	480	-	64	170	360
Juniata R. @ Newport,Lcl.	1324	1722	58	210	480	1150	42	44	165	140	330	260	1050	900	23	90	195	430
Juniata R. @ Newport	3354	4218	40	160	300	950	25	28	120	115	245	235	850	550	-	82	175	355
Susquehanna R., Harrisburg,Lcl.	2679	3902	100	240	600	1100	85	-	210	200	560	480	1100	1550	-	145	330	850
Susquehanna R. Harrisburg	24100	33770	55	180	330	750	36	-	145	130	280	255	605	680	-	90	190	390
Susquehanna R. @ Marietta,Lcl.	1890	2678	-	180	370	700	-	-	135	130	290	340	590	760	-	80	250	500
Nanticoke R. nr. Bridgeville	75	90	23	130	410	1050	-	-	100	55	380	220	980	980	-	26	115	480
Little Patuxent R. @ Guilford	38	40	23	110	340	800	15	-	76	-	300	160	760	520	-	-	90	290
Susquehanna R. @ Towanda, Pa.,Lcl.	1535	1998	-	190	470	1150	-	-	170	200	410	630	1050	1250	-	145	370	880

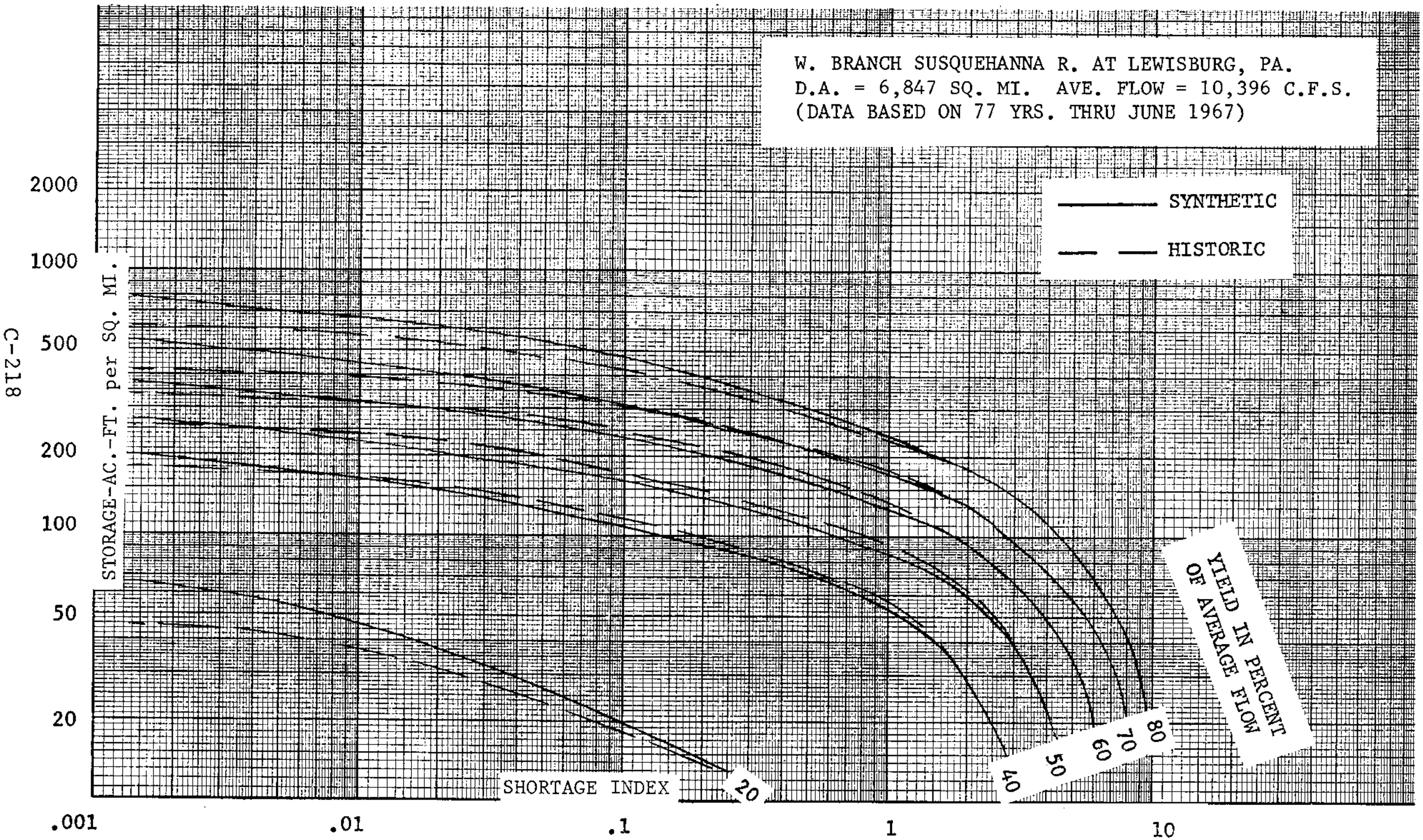
H = Historic record

S = Synthetic record

S.I. = Shortage Index

Lcl = local area above station

FIGURE C-42. SAMPLE YIELD-STORAGE CURVES - SUB-REGION E



considered to have recurrence intervals of approximately 50 years.

The Susquehanna River diversion facility to Area 18 was dedicated in January 1966. Under the terms of the contract between Baltimore and the Philadelphia Electric Co., the City is limited to 200 c.f.s. when the water level at Conowingo Dam is below spillway level and the river flow exceeds 5,000 c.f.s., and to 100 c.f.s. when the

TABLE C-75
EXISTING MINIMUM STREAMFLOW - SUB-REGION E 1/
(Cubic feet per second)

	MONTHLY	7-DAY
Sub-area 17a	630	400
Sub-area 17b	620	420
Sub-area 17c	480	270 (660)
Sub-area 17d	1,620	585
Sub-area 17e 2/	480	310
AREA 17	3,830	1,985 (2,375)
Sub-area 18a 3/	700	605
Sub-area 18b	1,200	840
AREA 18	1,900	1,445
SUB-REGION E	5,730	3,430 (3,720)

1/ Figures in parentheses include allowance for Lake Raystown
2/ Does not include yield developed for export to Area 15.
3/ Does not include yield developed for export to Area 19.

river flow is 5,000 c.f.s. or less. Diversion exceeding these limits would result in a capacity-loss charge by the electric company.

For NAR Supply Model analyses, it has been assumed that the diversion corresponding to existing conditions would be 65 m.g.d. (about 100 c.f.s.).

The interbasin diversion to Area 19, from the Patuxent River below Triadelphia and Rocky Gorge Reservoirs in Area 18, has been assumed to be 40 m.g.d., approximately equal to the yield based on historic records and the average quantity pumped during recent low flow seasons. As covered in the Sub-region D Summary existing diversion from Area 17 (Octoraro Creek) to Area 15 was considered to be 25 m.g.d.

Minimum flow, reservoir yield and diversion data have been used in studies of existing and practical development resource covered in Appendix E and in connection with NAR Supply Model Analyses.

SUB-REGION F

Major river basins comprising Sub-region F are the Potomac, Rappahannock, York and James. Atlantic Ocean influences and the Blue Ridge and Appalachian Mountain Ranges have distinct effects on the climate and hydrology of the Sub-region.

Precipitation ranges from 30 to 52 inches throughout the Sub-region, with an annual average of about 42 inches. Average snowfall varies from 70 to 80 inches in the mountainous areas to from 10 to 15 inches along the coast. Maximum rainfall occurs as a result of thunderstorms, hurricanes or coastal storms. Most locations have received rainfall in excess of 5 inches with a 24-hour period.

The mean annual temperature is about 56° F., ranging from 52° F. to 61° F., north to south, except in some areas of higher elevation. Prevailing winds are from the south and west, averaging about 10 m.p.h. Mean annual lake evaporation is approximately 36 inches. Average annual evapotranspiration is about 28.5 inches.

Sub-region F's average annual runoff is about 13.5 inches, with a relatively even geographic distribution. Floods caused by hurricanes, thunderstorms and extratropical cyclones can be very severe. The August 1969 hurricane was a rare phenomena, effecting most of the southern Sub-region, and responsible for record peak discharges. Overall, the drought of the 1960s seems to have been less severe, in terms of deficient runoff, than in many other parts of the Region. The existing minimum seven-day flow is equivalent to about 0.66 c.s.m.(Shortage Index 0.01).

Sediment and dissolved solids concentrations are low to moderate, and surface waters are soft, except in the mountains. Ground water is most productive in the Coastal Plain. However, the geologic formation is thinner here than in the Coastal Plain in other parts of the NAR, and Sub-region F development is generally for smaller supplies.

The major rivers empty into lower Chesapeake Bay, which is about 40 miles wide at the mouth of the Potomac River.

CLIMATE AND METEOROLOGY

Meteorologic Records

Sub-region F, like the other five NAR Sub-regions, is represented by a network of meteorologic data gathering stations which supply information on precipitation, snow and temperature. The records, most of which have been gathered over periods of many years, are adequate for an average climatic description. Figure C-43 shows the locations of selected stations referred to in this Summary.

Precipitation

Sub-region F receives about 42 inches of precipitation each year. The precipitation is distributed fairly evenly over the Sub-region, with annual averages varying from 30 to 52 inches. Area 19's average precipitation ranges from 30 to 35 inches in the foothills of the Alleghany Mountains to about 54 inches in the headwaters of the North Branch Potomac River. The average in Area 20 varies from 40 to 46 inches, and it is generally highest near the coast and in the western portion of the Area and lowest in the central part. Average annual precipitation in the James River Basin, Area 21, is about 43 inches, with variations of about 5 or 6 inches. Table C-76 lists precipitation data for selected stations in the Sub-region.

There is a distinct seasonal variation in precipitation, with a minimum amount of about 8.7 inches in October, November and December, 9.3 inches in the winter and 10.8 inches during the spring. The maximum rainfall. slightly over 13 inches, occurs during the months of July, August and September. November and February, with averages of about 2.75 inches, have the least precipitation.

Snowfall generally decreases in a southerly direction, and is significantly higher in the interior at higher elevations. Spruce Nob, W. Va., (Elevation 3,050 ft.) with 72.3 inches annually, and Bayard, W. Va., (Elevation 2,375 ft.) with 79.4 inches, have recorded the maximum annual snowfalls. The coastal area of the Sub-region receives less snowfall, on the order of from 10 to 15 inches per year. Table C-77 lists snowfall data for selected stations.

In addition to the extremes in weather occurring through the normal weather patterns, tropical and extratropical storms cause substantial damage through high winds and excessive rainfall. The most frequent storms are thunderstorms, 85% of which occur between May and September. Sporadic thunderstorms are often very important sources of precipitation in small watersheds. Hailstorms, or intensely developed thunderstorms, are particularly damaging to the tobacco industry in Virginia. Following in frequency of occurrence are hurricanes and tornadoes. Hurricanes are responsible for excessive rainfall on occasion.

A maximum rainfall of 27 to 28 inches occurred in Nelson

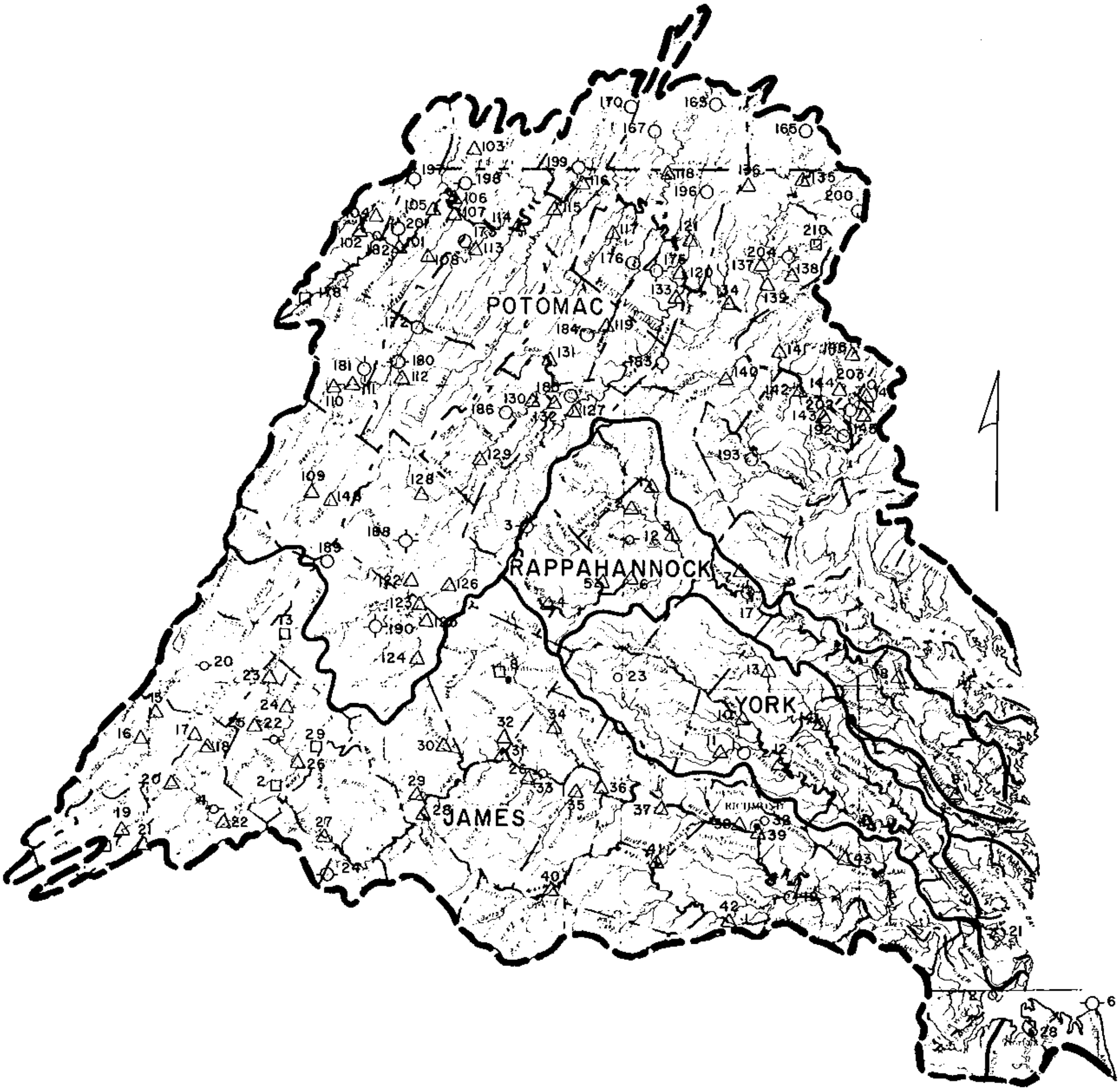


FIGURE C-43

METEOROLOGIC AND STREAMFLOW STATIONS
SUBREGION F

10 0 10 20 30 40
SCALE IN MILES

LEGEND

- PRECIPITATION
- PRECIP. & TEMP.
- PRECIP. & SNOW
- PRECIP., TEMP & SNOW
- TEMPERATURE
- TEMP. & SNOW
- SNOW
- STREAMFLOW STATIONS

TABLE C-76

PRECIPITATION DATA (a) -SUBREGION F (in inches)

Station	Map Code	Years of Record	Elevation ft., m.s.l.	Item	Monthly Data Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Annual
Chambersburg, Pa.	163	69	640	Max	6.31	4.99	6.48	9.18	7.94	9.21	7.95	8.63	9.21	7.86	7.59	5.50	
		69		Min	.51	.27	.91	.97	.68	.64	.60	.93	.16	.11	.58	.25	
		30		Mean(b)	3.02	2.32	3.77	3.46	4.10	4.08	3.95	4.08	3.30	3.15	3.12	2.98	39.37
Hancock Fruit Lab, Md.	199	56	428	Max	5.48	4.70	7.96	8.18	7.85	8.19	6.90	7.83	7.36	8.46	5.88	4.41	
		56		Min	.20	.27	.69	.64	.75	1.49	.21	.53	.13	T	.34	.17	
		30		Mean(b)	2.73	2.10	3.44	3.08	3.88	3.80	3.52	3.41	2.90	3.28	2.55	2.50	37.19
Frederick WB Ap, Md.	204	17	294	Max	4.22	4.20	5.35	10.53	8.16	11.26	8.82	9.59	5.27	3.44	5.95	4.91	
		17		Min	.35	1.41	1.46	1.58	.25	.85	1.26	.23	.99	.30	.72	.15	
		30		Mean(b)	2.98	2.55	3.53	3.67	3.91	3.60	3.92	4.30	3.42	3.13	2.93	2.89	40.83
Moorefield, ISSE, W.Va.	172	63	800	Max	6.73	7.60	5.09	7.26	8.09	9.86	6.86	8.07	6.43	7.75	4.00	4.97	
		63		Min	.12	.10	.80	.61	.61	1.35	.54	.84	.41	.08	.17	.30	
		63		Mean	2.19	2.00	2.62	2.64	3.30	3.79	3.35	3.25	2.39	2.28	1.74	1.99	31.54
Winchester, Va.	184	59	760	Max	5.66	4.63	7.94	8.29	7.97	9.41	11.19	11.16	12.20	15.01	6.28	5.87	
		59		Min	.33	.20	.43	.69	.47	1.38	.40	.53	.25	0.00	.25	.26	
		30		Mean(b)	2.39	2.12	3.16	3.11	4.10	3.70	4.24	4.16	2.97	3.45	2.59	2.48	38.47
Manassas, Va.	193	49	318	Max	7.91	5.38	6.00	5.86	11.48	8.55	11.72	13.54	10.26	10.82	7.18	6.00	
		49		Min	.13	.78	.59	.30	.76	.69	.91	.88	.84	.02	.65	.26	
		30		Mean(b)	3.18	2.35	2.94	3.07	4.14	3.51	4.69	5.16	3.52	3.52	3.01	2.72	41.81
Washington WB, City	202	95	72	Max	7.09	6.84	9.17	9.13	10.69	10.94	10.63	14.41	10.81	10.61	7.18	7.56	
		95		Min	.30	.33	.57	.31	.80	.80	.67	.30	.14	0.00	.05	.19	
		95		Mean	3.29	3.00	3.72	3.28	3.62	3.88	4.31	4.38	3.56	2.87	2.68	3.04	41.63
Staunton, Va.	190	79	1480	Max	6.22	3.82	7.48	5.66	8.26	7.34	8.43	8.61	9.49	8.29	5.21	6.78	
		79		Min	.87	.20	1.05	.47	.19	.59	.86	.55	.34	.13	.34	.11	
		30		Mean(b)	2.67	2.11	3.17	2.98	3.74	3.69	4.01	3.82	3.29	2.83	2.41	2.70	37.42
Lynchburg WBAP, Va.	**24**	**94**	**916**	Max	7.27	7.84	9.01	8.33	9.42	8.48	10.94	14.87	10.69	9.86	9.65	8.72	
				Min	.76	.42	.36	.87	.44	.67	.19	.30	.31	.04	.03	.13	
				Mean	3.29	2.65	3.61	3.14	3.21	4.06	4.21	4.41	3.36	2.64	2.58	3.14	40.30
Fredericksburg, Va.	**17**	**74**	**50**	Max	7.98	6.79	8.02	7.76	9.12	9.20	16.20	13.74	9.90	14.44	6.51	7.90	
				Min	.36	.20	.82	.59	.63	.62	.74	.51	.40	.14	.36	.08	
				Mean(b)	3.20	2.38	3.28	3.10	3.56	3.34	4.89	5.10	3.45	3.35	2.04	2.80	41.29
Ashland 1 SW, Va.	**1**	**53**	**220**	Max	5.47	6.74	9.00	8.11	9.18	8.51	9.88	12.18	8.08	9.40	7.01	6.66	
				Min	.75	.36	.93	.62	.49	.86	.35	.49	.13	.26	.47	.51	
				Mean	3.00	3.01	3.22	3.08	3.41	3.55	4.09	4.43	3.26	3.40	3.34	3.07	40.83
Hopewell, Va.	**19**	**78**	**40**	Max	9.45	7.47	8.82	8.32	9.50	12.09	12.92	12.92	9.84	8.79	6.57	7.23	
				Min	.69	.70	.72	.56	.70	.54	.85	.53	.14	.27	.06	.60	
				Mean(b)	3.07	2.76	3.16	3.34	3.97	4.23	5.86	5.10	3.73	2.88	2.80	2.78	43.68
Langley AFB, Va.	**21**	**129**	**10**	Max	10.48	8.69	8.20	6.15	13.00	10.46	12.52	9.49	9.75	7.50	6.92	6.46	
				Min	.89	.27	1.21	.53	.25	.36	1.40	.83	.16	.04	.29	.69	
				Mean(b)	3.23	3.02	3.42	3.03	3.48	3.10	5.33	5.13	3.98	2.87	2.79	2.57	41.95
Cape Henry, WB City, Va.	6	91	16	Max	8.43	7.92	10.72	9.78	10.61	10.74	11.83	16.82	14.90	7.86	8.96	8.06	
				Min	.72	.36	1.02	.77	.18	.05	1.22	1.16	0.00	.45	.12	.27	
				Mean(b)	2.98	3.25	3.36	2.93	3.04	3.54	5.00	5.36	3.95	2.87	2.80	2.76	41.84
Big Meadows, Va.	3	30	3,535	Max	6.46	6.24	11.65	13.65	9.27	17.13	10.57	23.88	12.80	21.31	13.70	8.62	
				Min	.38	.70	1.05	1.25	1.18	1.42	1.82	1.13	1.07	.04	1.09	.20	
				Mean	3.26	3.15	4.11	4.12	4.25	4.42	4.57	5.72	4.61	4.73	4.03	3.37	50.31

(a) Based on years of record through 1965 except as otherwise noted.
(b) Data based on period 1931-1960.

TABLE C-77

SNOW DATA - SUBREGION F

Station	Map Code	Years of Record(a)	Elevation ft.,m.s.l.	Average Snowfall in Inches												
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cumberland Md.	198	45	945	4.5	4.2	7.3	0.7	0	0	0	0	0	0	1.5	4.4	22.6
Hancock Fruit Lab,Md.	199	38	428	7.4	7.2	6.1	1.0	0	0	0	0	0	0.2	0.8	4.5	27.2
Bayard,W.Va.	178	52	2375	18.0	17.5	15.9	6.2	0.2	0	0	0	0	1.1	6.5	14.0	79.4
Martinsburg FAA,AP, W.Va.	175	61	537	7.0	7.2	5.5	0.5	0	0	0	0	0	0.1	0.7	4.4	25.4
Frederick WB,AP.,Md.	204	45	294	4.0	3.7	5.3	0.2	0	0	0	0	0	0	1.0	3.5	17.7
Unionville,Md.	210	19	430	5.7	5.5	6.8	0.1	0	0	0	0	0	0.1	0.8	2.9	21.9
Moorefield-McNeill, W.Va.	180	45	800	7.6	4.9	5.7	0.4	0	0	0	0	0	T	1.5	3.9	24.0
Stounton D&B Inst., Va.	190	61	1480	6.8	6.7	4.0	2.0	0	0	0	0	0	0.1	1.1	3.9	24.6
Washington,D.C. AP	202	22	14	4.9	4.8	3.0	T	0	0	0	0	0	T	0.6	3.6	16.9
Big Meadows,Va.	3	24	3535	9.3	9.2	9.9	1.6	0	0	0	0	0	0.5	3.4	7.2	41.5
Culpeper,Va.	12	35	475	5.9	5.9	3.9	0.1	0	0	0	0	0	0	0.8	3.5	20.2
Fredericksburg,Va.	17	70	50	5.4	4.9	2.7	0.4	0	0	0	0	0	0.1	0.5	3.1	17.1
Langley AFB,Va.	21	44	10	2.8	2.3	1.2	0	0	0	0	0	0	0	0	1.8	8.1
Charlottesville 2W,Va.	8	68	870	6.0	5.6	3.3	0.3	0	0	0	0	0	0.1	0.7	3.5	19.5
Deerfield 2 NE,Va.	13	30	1720	5.7	7.6	5.4	0.1	0	0	0	0	0	0	1.0	5.1	25.2
Hot Springs,Va.	20	71	2197	6.6	6.4	4.5	1.2	0	0	0	0	0	0.1	1.4	5.0	25.0
Lexington,Va.	20	73	1060	6.2	5.4	3.8	0.3	0	0	0	0	0	0.1	0.7	4.2	20.6
Clifton Forge,Va.	10	27	1055	5.5	6.0	2.9	0.2	0	0	0	0	0	0	0.1	4.2	19.2
Pedlar Dam,Va.	29	13	1013	7.2	4.3	5.5	0	0	0	0	0	0	0	0.2	2.7	20.4
Buchanan,Va.	4	62	875	5.8	4.5	3.2	0.1	0	0	0	0	0	0	0.9	3.8	18.5
Catawba Sanitorium,Va.	7	34	1890	5.7	5.7	3.7	0	0	0	0	0	0	0	1.0	4.2	20.6
Lynchburg WBAP,Va.	24	41	916	4.8	3.8	3.2	0.1	0	0	0	0	0	0	0.5	2.6	15.0
Hopewell,Va.	19	61	40	3.9	3.2	1.7	0.1	0	0	0	0	0	0	0.2	2.0	11.3
Norfolk,Va.	28	76	10	2.8	2.6	1.5	0	0	0	0	0	0	0	0.1	1.9	8.9
Cape Henry,Va.	6	74	16	2.2	2.2	1.0	0	0	0	0	0	0	0	0	1.5	7.0

(a) Number of years used for computing annual values. Length of record may vary slightly for individual months.

County, Va., within an 8 hour period on August 19 and 20, 1969, as a result of Hurricane Camille. Almost every area within the Sub-region has recorded a 24-hour rainfall of 5 inches or more, caused by a thunderstorm, hurricane or coastal storm. The maximum monthly precipitation of 20.7 inches was recorded at Diamond Springs, Va., in September 1964. Most areas within the Sub-region have recorded monthly rainfall maximums of 10 inches of more, usually in the summer. The maximum annual precipitation of 72 inches was recorded at Charlottesville, Va., in 1937.

Sub-normal precipitation occurs quiet frequently, and occasionally on a Sub-regional scale. The drought of the early-1960s affected large portions of Sub-regions F and caused precipitation of about 76% of average in the northern portion. Another extensive and severe drought occurred in 1930 and 1931, when severe conditions existed for from 12 to 18 months and precipitation was 18 to 22 inches below average.

Temperature

The mean annual temperature in Sub-region F averages about 56° F., with the lower means recorded in the Appalachian Mountains. Annual means are as low as 47.4° F. at Bayard, W. Va., and the annual mean increases, north to south, from about 52° F. to 61° F.

The warmest temperatures occur in the month of July, ranging from a mean of 67° F. in the mountains to 79° F. in southern Virginia. The maximum recorded temperature was 110° F. at Columbia, Va. and several locations have reported highs of 109° F. January is the coldest month, with mean temperatures ranging from 29° F. in elevated areas to 44° F. in southern Virginia. Minimum recorded temperatures include -30° F. at Bayard, W. Va., and -26° F. near Hancock, Md. Table C-78 shows mean temperature data for selected stations in Sub-region F.

Humidity

Mean annual relative humidity averages about 70% in the interior and 80% along the coast. January and July averages are about the same as the annual; however, wide diurnal variations exist between seasons. At Washington D. C. where the relative humidity in July averages 84% at 1 a.m. and 53% at 1 p.m., the respective January averages are 70% and 56%. The mean dew point temperature is about 25° F. in January and 65° F. in July. The Sub-region's mean annual dew point temperature is about 45° F. The mean annual dew point temperature at Washington, D. C., is 44° F., and 49° F. at Norfolk, Va.

TABLE C-78

TEMPERATURE DATA (a) -SUBREGION F (in degrees Fahrenheit)

Station	Map Code	Years of Record	Elevation ft.,m.s.l.	Item	Annual Means	Monthly Means											
						Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		33		Mean Max	64.9	40.7	42.6	52.6	65.2	75.6	83.4	87.7	85.6	80.2	68.3	54.4	43.0
Hancock Fruit Lab,Md.	199	33	428	Mean Min	39.9	20.9	21.6	29.0	38.4	47.4	56.1	60.2	58.8	51.9	40.2	31.6	22.7
		33		Mean	52.4	30.7	32.2	40.8	51.8	61.6	69.7	73.9	72.2	66.1	54.2	43.0	32.9
		16		Mean Max	66.5	45.1	47.3	54.3	67.4	75.8	83.2	87.1	85.8	79.7	70.2	56.3	46.0
Petersburg,W.Va.	181	16	1013	Mean Min	41.9	24.8	25.7	31.1	41.4	49.4	57.0	61.2	59.9	52.6	42.1	32.9	24.9
		20		Mean	54.1	34.1	36.1	42.5	54.2	62.9	70.6	74.1	72.6	66.1	56.3	44.6	35.6
		66		Mean Max	66.6	43.8	45.6	55.5	66.5	76.3	84.0	87.9	86.0	80.6	69.7	57.1	45.7
College Park,Md.	203	66	70	Mean Min	43.2	24.2	24.6	32.3	40.8	50.5	59.8	64.5	62.5	56.0	43.8	33.9	25.9
		30		Mean	55.9	36.0	36.8	44.0	54.6	64.6	72.7	76.8	75.1	68.6	57.6	46.6	37.0
		30		Mean Max	65.8	44.3	46.1	53.8	65.8	75.5	83.4	87.0	85.0	78.6	68.3	56.5	45.6
Washington Nat'l.	202	30	14	Mean Min	48.2	29.5	29.4	35.8	45.6	56.0	64.9	69.3	67.9	60.7	49.6	38.9	30.5
AP,D.C.		30		Mean	57.0	36.9	37.8	44.8	55.7	65.8	74.2	78.2	76.5	69.7	59.0	47.7	38.1
				Mean Max	57.8	38.8	40.1	46.9	58.5	67.2	73.4	76.3	74.9	68.9	60.2	48.6	39.2
Big Meadows,Va.	3	30	3535	Mean Min	38.4	20.2	20.8	26.1	36.2	46.4	53.9	57.6	56.6	50.3	41.1	30.3	21.6
				Mean	48.1	29.5	30.4	36.5	47.4	56.7	63.6	66.9	65.8	59.6	50.7	39.5	30.3
				Mean Max	66.8	45.2	47.9	56.1	68.3	77.1	83.8	87.5	85.1	79.7	68.0	57.1	46.2
Culpeper,Va.	12	56	475	Mean Min	44.4	25.8	26.5	32.9	42.4	52.6	60.9	64.8	63.3	57.2	45.1	34.1	26.8
				Mean (b)	56.6	36.8	37.9	45.5	56.1	65.5	73.3	76.9	75.1	69.0	58.2	47.0	37.4
				Mean Max	67.8	46.8	48.5	58.1	68.1	77.4	84.0	87.8	85.7	80.4	70.2	59.1	48.0
Fredericksburg,Va.	17	72	50	Mean Min	45.1	26.5	26.3	34.0	42.8	52.9	61.5	66.0	64.3	58.0	46.1	35.4	2.70
				Mean (b)	56.6	37.1	38.0	45.0	55.6	65.3	73.3	77.2	75.5	69.1	58.3	47.3	37.9
				Mean Max	66.8	45.8	47.5	57.0	67.1	76.4	82.7	85.8	84.9	79.9	69.3	57.3	47.4
Lexington,Va.	22	87	1060	Mean Min	42.6	24.6	25.1	32.4	40.7	50.3	58.7	62.8	61.6	54.7	42.6	32.0	25.2
				Mean (b)	55.8	37.4	38.6	45.1	55.5	64.2	71.6	75.1	73.8	67.7	56.9	46.0	37.7
				Mean Max	69.6	48.3	51.7	59.7	70.5	79.3	85.9	88.7	87.2	82.3	72.2	59.3	49.5
Buchanan,Va.	4	47	875	Mean Min	44.0	26.8	28.2	33.8	42.2	50.9	59.2	63.0	62.2	56.0	44.2	34.2	27.6
				Mean (b)	56.8	38.4	39.9	46.2	56.5	65.3	72.7	76.0	74.8	68.8	58.1	46.8	38.5
				Mean Max	69.4	48.3	50.6	59.1	70.4	79.3	86.8	89.4	86.5	81.8	70.6	59.9	49.8
Richmond WBAP,Va.	32	30	162	Mean Min	46.9	29.0	29.2	36.3	45.8	54.6	63.4	66.7	65.4	58.6	46.7	37.1	29.5
				Mean	58.1	38.7	39.9	47.7	58.1	67.0	75.1	78.1	76.0	70.2	58.7	48.5	39.7
				Mean Max	68.2	49.8	51.0	57.8	66.9	76.1	83.6	87.0	85.2	79.8	70.0	60.0	51.3
Norfolk,Va.	28	95	10	Mean Min	52.1	34.4	34.7	40.3	48.5	58.0	66.4	70.8	70.3	65.6	55.2	44.6	36.5
				Mean (b)	59.7	41.2	41.6	48.0	58.0	67.5	75.6	78.8	77.5	72.6	62.0	51.4	42.5

(a) Based on years of record (through 1960) except as otherwise noted.
(b) Data based on period 1931-1960.

Wind

Sub-region F's prevailing winds are westerly, shifting to the southern quadrants during the summer. The mean velocity is approximately 10 m.p.h. Winds as high as 80 m.p.h. occur during the passage of hurricanes, but much of the severe wind damage is sustained during thunderstorms, which occur about 35 times annually.

Evaporation

Mean annual lake evaporation varies from 30 inches in the northern part of the Sub-region, to 40 inches in the south. Approximately 70% of the evaporation occurs from May through October.

HYDROLOGY

Existing Resource

Hydrologic Records. The sources of streamflow data are the U. S. Geological Survey and the Virginia Division of Water Resources. There are presently over 110 recording gages operated by the Survey, and 55 by the State agency. Additional data is available from the annual publication "Daily River Stages," published by the National Weather Service. Selected stream gaging stations referred to in this Appendix are located on Figure C-43.

Average Flow. Average flow is 31,095 c.f.s., equivalent to 13.5 inches of runoff over the drainage area of 31,270 square miles. This represents about 34% of average annual precipitation, considerably less than in the other five Sub-regions. Runoff on a per square mile basis is also less, averaging about 1 c.s.m. for the entire Sub-region The highest value is for Sub-area 21a, 1.2 c.s.m., and the lowest for Sub-area 14b, .85 c.s.m. Table C-79 shows estimated average runoff by Sub-area.

Streamflow Variation. Maximum monthly flows have occurred most often in March and generally amount to from four to eight times the average value. Minimum monthly flows have occurred most frequently in September and October, and less frequently in August, with minimum occurrences usually between 3%and 10% of average flow. Table C-80 lists average, maximum and minimum flows for selected gaging stations.

Existing Regulation. Sub-region F contains about 277,100 acre-feet of storage. Gathright Lake, which is under construction, accounts for nearly 75% of this total. Table C-5 (p. C-23) summarizes major storage capacities by Area.

TABLE C-79
AVERAGE ANNUAL RUNOFF - SUB-REGION F
(Drainage area in square miles, average runoff in c.f.s.)

	DRAINAGE AREA	AVERAGE RUNOFF
Sub-area 19a	4,073	4,000
Sub-area 19b	3,040	2,600
Sub-area 19c	7,557	7,275
AREA 19	14,670	13,875
Sub-area 20a	2,700	2,700
Sub-area 20b	3,300	3,000
AREA 20	6,000	5,700
Sub-area 21a	4,571	5,420
Sub-area 21b	4,949	5,100
Sub-area 21c	1,080	1,000
AREA 21	10,600	11,520
SUB-REGION F	31,270	31,095

TABLE C-80

STREAMFLOW DATA (a) - SUBREGION F

Location	Map Code	D.A., sq.mi.	Years of Record	Average Flow-c.f.s.	Mean Monthly Flow-c.f.s. Maximum	Date	Minimum	Date	Structures Affecting Natural Streamflow
Georges Cr. at Franklin, Md.	104	72.4	35 (thru'64)	78.0	682	3/36	1.78	10/30	
Wills Cr. nr. Cumberland, Md.	106	247	35 (thru'64)	315	2,410	3/36	11.9	10/30	Some diversion
N. Branch Pot. R. nr. Cumberland, Md.	107	875	35 (thru'64)	1,217	8,763	3/63	28.9	10/30	Stony R. & Savage R. Res.
So. Branch Pot. R. nr. Petersburg, W. Va.	111	642	36 (thru'64)	686	4,090	3/36	49.3	10/30	
S. Fork S. Branch Pot. R. nr. Moorefield, W. Va.	112	283	33 (thru'64)	209	1,086	3/63	11.1	8/30	
S. Branch Pot. R. nr. Springfield, W. Va.	113	1,471	40 (thru'64)	1,248	10,490	3/36	73.5	8/30	
Cacapon R. nr. Gt. Cacapon, W. Va.	115	677	41 (thru'64)	563	5,405	3/36	39.4	9/32	
Pot. R. at Hancock, Md.	116	4,073	32 (thru'64)	3,981	32,280	3/36	309	10/41	Stony R. & Savage R. Res.
Conococheague Cr. at Fairview, Md.	118	494	36 (thru'64)	558	3,557	3/36	42.3	10/30	Small powerplants
Antietam Cr. nr. Sharpsburg, Md.	121	281	42 (thru'64)	264	1,290	3/36	58.6	9/63	Diversion into basin
North R. nr. Burketown, Va.	122	375	40	365	1,932	3/36	34.2	9/30	
Middle R. nr. Grottoes, Va.	123	360	38	301	1,704	3/36	56	8/64	
S. Fork Shenandoah R. nr. Lynnwood, Va.	126	1,076	35	969	5,764	3/36	122	10/30	
S. Fk. Shen'doah R. at Front Royal, Va.	127	1,638	42	1,579	10,300	3/36	225	10/30	powerplants
N. Fk. Shen'doah R. at Cootes Stove, Va.	128	215	40	184	1,536	3/36	0.52	8/30	
N. Fk. Shen'doah R. nr. Strasburg, Va.	130	772	40	564	5,017	3/36	58.9	10/30	
Shenandoah R. at Milville, W. Va.	133	3,040	50	2,649	17,540	3/36	343	10/30	Hydroelectric plants
Pot. R. at Pt. of Rocks, Md.	134	9,651	70	9,173	68,360	3/36	706	10/30	Stony R. & Savage R. Res.
Monocacy R. nr. Frederick, Md.	137	865	34 (thru'30)	943	4,677	3/02	38.8	8/30	
Mon. R. at Jug Bridge nr. Fred., Md.	139	817	35 (thru'64)	882	4,345	3/36	46.8	10/30	
Goose Cr. nr. Leesburg, Va.	140	338	37	297	2,265	10/42	1.86	8/30	
Difficult Run nr. Gt. Falls, Va.	142	58	31	54.4	163	2/36	3.61	8/57	
Pot. R. nr. Wash., D.C.	143	11,560	34 (thru'64)	10,990	76,510	3/36	569	8/30	Stony R. & Savage R. Res., div.
N.W. Branch Anacostia R. nr. Colesville, Md.	146	21.3	41 (thru'64)	22.0	-	-	-	-	Diversions
Jackson R. at Falling Spring, Va.	15	409	40	480	2,754	3/63	62.5	9/30	
Cowpasture R. nr. Clifton Forge, Va.	17	456	40	512	2,512	3/63	45.4	10/30	
James R. at Lick Run, Va.	18	1,369	40	1,573	8,393	3/63	178	10/30	
Craig Creek at Parr, Va.	20	331	40	373	1,922	3/55	34.1	9/32	
James R. at Buchanan, Va.	22	2,084	67	2,465	11,460	3/55	289	(9/30) (8/64)	
Maury R. at Rockbridge Baths, Va.	24	329	37	356	2,017	3/36	14.9	8/64	
James R. at Holcombs Rock, Va.	27	3,250	39	3,492	15,510	3/36	421	9/30	powerplants
James R. at Bent Cr., Va.	28	3,671	41	4,120	17,410	3/36	424	10/30	powerplants
James R. at Scotsville, Va.	31	4,571	41	5,026	20,320	3/36	499	10/30	powerplants
Rivanna R. at Palmyra, Va.	34	675	32	681	3,662	4/37	19.1	9/54	
Willis R. at Flanagan Mills, Va.	35	247	39	241	1,380	1/36	7.03	9/30	Trice Lake
James R. at Cartersville, Va.	36	6,242	67	7,015	28,610	3/99	528	10/30	powerplants
James R. nr. Richmond, Va.	39	6,757	31	7,351	27,370	3/36	144	9/54	powerplants, diversions
Appomattox R. at Mattoax, Va.	41	729	44	703	4,566	8/40	30.0	9/32	
Appomattox R. nr. Petersburg, Va.	42	1,335	39	1,165	6,803	8/40	32.3	9/32	
Chickahominy Forge nr. Prov. Forge, Va.	43	249	23	271	1,445	8/55	7.42	9/54	
Rapidan R. nr. Culpeper, Va.	6	465	35	501	3,163	10/42	8.1	10/30	
Rapp. R. nr. Fredericksburg, Va.	7	1,599	58	1,627	11,090	10/42	15.3	10/30	
North Anna R. nr. Doswell, Va.	10	439	39	380	2,220	8/28	5.5	10/30	
South Anna R. nr. Ashland, Va.	11	393	35	354	1,968	4/37	6.5	9/32	
Mattaponi R. nr. Beulahville, Va.	14	619	24	576	2,206	3/62	18.4	9/54	

Note: Stations are not necessarily listed in the usual downstream order. Refer to map code number sequences.

Two significant interbasin diversions exist. One is the diversion from Area 18 into the Washington, D.C., area, covered in the Sub-region E Summary; and the other from the Chowan River Basin, south of the North Atlantic Region, into Area 21. The latter has a present transfer capacity of approximately 50 m.g.d., although only up to 17 m.g.d. is currently imported for use in the area of Norfolk, Va.

Quality and Suitability. The natural waters of Sub-region F are generally of good quality. They can be generally classed as the calcium-magnesium type throughout. Hardness is significant in much of the Potomac Basin and in the headwaters of the Rappahannock and James Rivers. Suspended sediment concentrations are moderate, except around Washington, D.C., and in the central portions of the York and James Basins. Annual sedimentation rates vary from 86 tons per square mile in Area 20 to 118 tons per square mile in Area 19 (See Appendix Q, Erosion and Sedimentation).

Industrial and non-industrial waste sources discharge about 3 million population equivalents (PE) of biodegradables, as measured by biochemical oxygen demand (BOD), into the water of the Sub-region. These two sources are almost equal, with the non-industrial contribution about 0.1 million PE higher than the industrial load. (See Appendix L, Water Quality and Pollution.) Other major sources of pollution are discharges from thermal-electric power plants, commercial navigation, urban and rural runoff, and sedimentation.

Water quality problem areas include the North Branch Potomac River (acid mine drainage as well as municipal and industrial wastes), the Potomac River Estuary, the James River Estuary and sections of the James River below Lynchburg. Va., and Lick Run, Va.

Floods. Very heavy rains in Sub-region F may be the result of an intense extratropical cyclone, a hurricane or a thunderstorm. If an extratropical storm coinsides with a period of snowmelt and thawing of the ground, then the flooding becomes even more critical, as was the case with the March 19, 1936, flood in the Potomac River Basin.

Continuously recorded streamflow data are supplemented by historical records such as high water marks, newspaper clippings and personal accounts. Historical information indicates that the 1870 flood on the Shenandoah River was higher than the flood of 1936. The 1889 flood was of approximately the same magnitude as that of 1936 on the Potomac River near Washington, D. C., with a flow of about 484,000 c.f.s.

Recorded data of long duration is lacking in the Rappahannock

River Basin. Records show that the flood of October 16, 1942 resulted in the highest peak at Fredericksburg, Va., followed by the floods of April 26, 1937 and August 19, 1955, with respective flows of 140,000 c.f.s., 134,000 c.f.s. and 74,500 c.f.s.

The York River is essentially an estuary fed by two main tributaries, the Pamunkey and Mattaponi Rivers. The flood of record on the Pamunkey, with a discharge of 40,300 c.f.s. at Hanover, Va., resulted from precipitation associated with Hurricane Camille on August 19 and 20, 1969. According to historical data, the peak flood on the Mattaponi, with a discharge of 15,000 c.f.s. near Bowling Green, Va., occurred during August 1928.

The James River was seriously affected by precipitation related to the passage of Hurricane Camille, when some parts of the Basin received 27 to 28 inches of rain and discharges in many rivers greatly exceeded previous extremes. The peak flow on the James near Richmond, Va., was 220,000 c.f.s. on 21 August 1969, more than 25% greater than the previous record flow of 175,000 c.f.s. in March 1936.

Table C-81 lists the greatest recorded floods for selected stations in the Sub-region, and frequency relationships for a few of these stations are contained in Table C-3 (p. C-17).

Low Flow. Most of Virginia, Maryland and parts of Pennsylvania and West Virginia received about 60% of average rainfall in 1930 and about 90% in 1931, resulting in runoff which was well below normal. The annual flow on the Shenandoah River at Millville, W. Va., was 1,200 c.f.s., or 46% of average, in Water Year 1931, and 64% in 1932. On the Potomac River at Point of Rocks, Md., the flow was 53% of average in 1931 and 76% in 1932. During Water Years 1965 and 1966, respective annual lows were 77% and 46% of average at Millville, and 83% and 53% of average at Point of Rocks.

The flow in the Rappahannock River at Fredericksburg, Va., was only 27% of average during Water Year 1931, and 51% for Water Years 1930 through 1932, 56% during Water Year 1966, and 67% for the period from Water Year 1962 through Water Year 1966.

Ground Water. Parallel northeastern trending formations divide Sub-region F into five natural ground water provinces. Traversing the Sub-region from east to west are the Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau Provinces.

The Coastal Plain, which is underlain by strata of unconsolidated sand, salt, clay and marl, is a productive ground water area. Some of the aquifers occur under artesian conditions, while others occur under water table conditions. One of the factors

TABLE C-81

FLOOD DATA - SUBREGION F

Location	Map Code	Latest Data (W.Year)	Flood No. 1 Date	Flood No. 1 Peak Q. c.f.s.	Flood No. 1 Stage, ft.	Flood No. 1 $Q/(D.A.)^{.5}$	Flood No. 2 Date	Flood No. 2 Peak Q. c.f.s.	Flood No. 2 Stage, ft.	Flood No. 2 $Q/(D.A.)^{.5}$	Flood No. 3 Date	Flood No. 3 Peak Q. c.f.s.	Flood No. 3 Stage, ft.	Flood No. 3 $Q/(D.A.)^{.5}$
Georges Cr. at Franklin, Md.	104	1964	3/17/36	8,500	9.6	1000	4/26/37	7,800	9.0	918	10/15/42	4,830	11.08	568
Wills Cr. nr. Cumberland, Md.	106	1964	3/17/36	38,100	20.2	2427	10/15/42	23,300	15.14	1484	4/26/37	18,600	13.4	1854
W. Br. Potomac R. nr. Cumberland, Md.	107	1964	6/ 1/89	89,000	29.2	3009	3/17/36	88,200	29.1	2980	3/29/24	82,000	28.4	2772
So. Br. Pot. R. nr. Petersburg, W. Va.	111	1964	6/17/49	62,000	22.83	2443	3/17/36	49,800	20.3	1962	2/ 4/32	28,300	15.18	1115
S. Fk., S. Br. Pot. R. nr. Moorfield, W. Va.	112	1964	6/18/49	39,000	16.1	2321	3/17/36	30,400	14.9	1810	5/25/24	28,000	13.5	1667
S. Br. Pot. R. nr. Springfield, W. Va.	113	1964	3/18/36	143,000	34.2	3734	11/10/1877	140,000	34.0	3650	6/18/49	104,000	29.85	2715
Cacapon R. nr. Great Cacapon, W. Va.	115	1964	3/18/36	87,600	30.1	3369	5/31/1889	57,500	24.7	2210	8/19/55	55,500	24.30	2135
Pot. R. at Hancock, Md.	116	1964	3/18/36	340,000	47.6	5338	5/31/1889	220,000	40.0	3447	10/16/42	155,000	36.63	2433
Conococheaque Cr. at Fairview, Md.	118	1964	11/22/52	17,100	15.16	770	12/ 1/34	16,300	14.8	734	3/12/53	15,500	14.44	698
Antietam Cr. nr. Sharpsburg, Md.	121	1964	7/20/56	12,600	16.73	752	7/18/49	6,470	11.23	386	7/11 or 12/28	6,300	11.9	376
North R. nr. Burketown, Va.	122	1965	6/18/49	62,600	36.3	3235	10/15/42	43,000	32.4	2222	3/17/36	37,000	26.70	1912
Middle R. nr. Grottoes, Va.	123	1965	3/18/36	24,500	28.57	1292	10/15/42	21,100	26.3	1112	6/18/49	16,100	22.74	849
S. Fk. Shenandoah R. nr. Lynnwood, Va.	126	1965	10/15/42	80,000	27.2	2439	3/18/36	77,000	26.57	2348	6/18/49	53,600	23.60	1634
S. Fk. Shenandoah R. at Front Royal, Va.	127	1965	10/16/42	130,000	34.8	3415	3/18/36	98,000	26.0	2425	3/ 1/02	76,800	23.5	1900
N. Fk. Shenandoah at Cootes Stove, Va.	128	1965	10/15/42	50,000	25.3	3413	3/17/36	40,500	23.25	2765	12/ 1/34	24,600	19.0	1679
N. Fk. Shen. R. nr. Strasburg, Va.	130	1965	10/16/42	100,000	31.2	3597	3/18/36	89,000	30.2	3201	8/18/55	36,100	23.55	1299
Shenandoah R. at Milville, W. Va.	133	1965	10/16/42	230,000	32.4	4200	3/18/36	150,000	26.4	2740	10/ 1/1896	105,000	22.0	1910
Potomac R. at Pt. of Rocks, Md.	134	1965	3/19/36	480,000	41.03	4920	6/ 2/1889	460,000	40.2	4775	10/16/42	418,000	40.43	4300
Monocacy R. nr. Frederick, Md.	137	1930	6/ 1/1889	46,000	35.0	1780	9/ 1/11	26,600	27.5	1020	3/ 1/02	25,700	27.2	995
Mon. R. at Jug Bridge nr. Frederick, Md.	139	1964	6/ 1/1889	56,000	30.0	1960	8/24/33	51,000	28.1	1780	4/27/37	33,800	21.7	1180
Goose Cr. nr. Leesburg, Va.	140	1965	8/26/37	45,000	26.86	2380	10/16/42	45,000	22.9	2380	7/21/56	32,800	20.9	1730
Difficult Run nr. Great Falls, Va.	142	1965	7/21/56	3,190	10.96	420	8/13/55	2,960	10.70	390	6/13/36	2,890	10.58	380
Potomac R. nr. Washington, D.C.	143	1964	3/19/36	484,000	28.1	4450	10/17/42	447,000	26.88	4120	4/28/37	347,000	23.3	3230
Jackson R. at Falling Spring, Va.	15	1966	3/ -/13	50,000	20.00	2480	3/11/36	24,700	14.74	1220	5/16/42	20,100	13.65	1000
Cowpasture R. nr. Clifton Forge, Va.	17	1966	3/ -/13	45,000	20.80	2100	3/18/36	34,200	18.62	1600	5/17/42	18,500	14.07	870
James R. at Lick Run, Va.	18	1966	11/ -/77	120,000	33.00	3240	3/ -/13	98,000	30.40	2650	3/18/36	66,600	25.65	1800
Craig Ct. at Parr, Va.	20	1966	1/23/35	19,100	17.00	1050	8/17/28	16,900	15.60	930	8/13/40	15,200	15.02	830
James R. at Buchanan, Va.	22	1966	11/ -/77	125,000	34.9	2740	3/27/13	105,000	31.00	2300	4/ -/86	85,000	27.00	1860
Maury R. at Rockbridge Baths, Va.	24	1966	3/17/36	33,000	13.07	1820	5/22/42	17,500	10.53	960	6/18/49	15,600	10.07	860
James R. at Holcombs Rock, Va.	27	1966	3/28/13	118,000	31.30	2070	3/18/36	115,000	30.78	2020	1/23/35	86,300	26.61	1510
James R. at Bent Cr. Va.	28	1966	9/30/1870	150,000	27.00	2480	11/24/1877	125,000	24.00	2060	3/18/36	115,000	23.02	1900
James R. at Scottsville, Va.	31	1966	11/ -/77	160,000	27.9	2370	9/19/44	133,000	26.00	1970	8/16/40	130,000	25.84	1930
Rivanna R. at Palmyra, Va.	34	1966	10/16/42	78,000	36.50	3000	4/26/37	56,700	33.35	2180	3/18/36	39,900	29.26	1530
Willis R. at Flanagan Mills, Va.	35	1966	4/27/37	9,580	23.86	610	4/19/55	8,100	21.35	520	9/ 6/35	8,000	-	510
James R. at Cartersville, Va.	36	1966	9/20/44	180,000	29.60	2280	3/19/36	166,000	28.77	2100	8/17/40	145,000	28.34	1840
James R. nr. Richmond, Va.	39	1966	3/19/36	175,000	23.42	2130	8/18/40	151,000	21.80	1840	9/20/44	150,000	21.80	1830
Appomattox R. at Mattoax, Va.	41	1966	8/18/40	35,000	35.30	1300	4/28/37	20,100	29.97	750	5/25/01	13,400	25.30	500
Appomattox R. nr. Petersburg, Va.	42	1966	8/20/40	28,000	18.15	770	4/30/37	18,800	14.85	520	7/26/38	18,200	14.58	500
Chickahominy Forge nr. Prov. Forge, Va.	43	1966	8/15/55	7,710	11.67	490	7/21/45	5,750	10.60	360	1/ 8/62	2,660	9.73	170
Rapidan R. nr. Culpeper, Va.	6	1966	10/16/42	58,100	30.30	2700	4/26/37	50,000	28.03	2320	8/18/55	33,800	24.31	1570
Rappahannock R. nr. Fredericksburg, Va.	7	1966	10/16/42	140,000	25.90	3600	4/26/37	134,000	25.14	3350	8/19/55	74,500	17.00	1860
North Anna R. nr. Doswell, Va.	10	1966	4/27/37	18,300	33.58	880	8/20/55	12,400	25.58	590	10/17/42	11,600	24.54	550
South Anna R. nr. Ashland, Va.	11	1966	4/28/37	13,700	22.77	690	7/21/56	12,800	22.22	650	9/ 6/35	8,740	19.04	440
Mattaponi R. nr. Beulahville, Va.	14	1966	7/20/45	8,700	20.00	350	10/20/42	7,490	18.65	300	12/ 8/48	7,280	18.82	290

Note: Stations are not necessarily listed in the usual downstream order. Refer to map code number sequences.

limiting the withdrawal of Coastal Plain ground water is the recharge rate of the aquifer. A given volume of water must also be maintained to prevent the salt front from advancing inland. Also, water levels are declining as a result of increased urbanization which increases direct runoff and decreases recharge. The water of the Coastal Plain aquifers is of generally good quality, with low to moderate mineral content and moderate hardness.

The Valley and Ridge Provivce is also a productive ground water area. Its valleys are underlain by dolomite, limestone and shale, while the ridges are composed mostly of sandstones. Natural quality of the ground water is good, despite the fact that it is hard because of an excess of carbonates. The water is often contaminated by undesirable amounts of nitrates and chlorides.

The Piedmont Province, which borders the Coastal Plain Province on the west, is a dissected plateau composed of a series of deformed ancient sedimentary rocks, igneous rocks and metamorphic rocks, with some triassic diabase, sandstones and shale. The presence of ground water is related to the degree of faulting with associated joints, cleavage planes, fissures, etc. As aquifers, these rocks are low to moderate water bearers, with production generally ranging from a few gallons per minute to 30 g.p.m. Ground water of the Piedmont Province is moderately hard and generally low in dissolved mineral content. However, locally, iron is a troublesome constituent in many wells, and silica is also highly concentrated in some wells.

The least productive ground water source is the Blue Ridge Province, which is composed of granite and gneissic rocks of pre-Cambrian age. Water is confined to fractures, joints and contact zones, and yields are usually less than 20 g.p.m. The quality of the water is generally good in that it is relatively soft with low dissolved solids concentrations.

Estuaries and Coastal Areas. The shoreline of Sub-region F forms the lower western shore of Chesapeake Bay, into which several large rivers with broad estuaries drain. The Bay and its tributary estuaries provide a vast source for many water uses including recreation, sport and commercial fishing, and power cooling. The Potomac River contributes over 20% of the fresh water runoff into the Bay, and the Rappahannock, York and James Rivers, combined, contribute nearly 25%.

Mean tidal range at the inlet to the Bay is about 3 feet, and at the river entrances ranges between 1.5 to 2.5 feet. Minimum and maximum sea-surface temperatures,at the inlet, average 70°F. and 82°F. in summer and 35°F. and 60°F. in winter. Mean sea - surface salinity varies between about 31 ot 32.5 parts per thousand in summer and winter respectively.

Water Availability Analyses

Evapotranspiration. The normal annual evapotranspiration ranges from 25 inches in western Maryland to approximately 32 inches in southeastern Virginia. The normal July evapotranspiration ranges between 5.5 and 6.5 inches, or about 20% of the annual total. Considering the normal annual precipitation of about 42 inches and runoff of 13.5 inches, and assuming no change in ground water storage, the average annual rate of evapotranspiration would be 28.5 inches. Average annual reservoir surface evaporation is about 36 inches with about 5.5 inches occurring in July. Thus the net annual loss would be 7-8 inches. This figure is subject to wide seasonal and geographic variation. There may, however, be short-terms gains, such as on a seasonal basis, since all precipitation is intercepted by the lake surface before some seepage into the ground.

Streamflow Simulation. The method used to estimate missing monthly streamflow records through 1967, as described in detail in Chapter 3, was accomplished for the key stations shown in Table C-82. The numeral at the left indicates the grouping of stations for correlation analysis. Schematic diagrams of the stations showing relative location and incremental or local area are shown in Figure C-44. The groups of stations were also used for the generation of streamflow in ten 100-year periods at each station. The stations cover a drainage area of 22,951 square miles with an average local area of about 1,060 square miles.

Table C-83 shows a comparison between historic and generated streamflow volumes for 1-,6- and 54-month durations. The synthetic data represent the highest and lowest 100-year traces with respect to the specified volumes. The maximum volumes for 1- and 6-month durations for the historic record are, in general, less than either the highest or lowest of the 10 generated records. In most cases, the minimum volumes occurred in the generated traces, with the historic record having higher values than any of the 10 generated periods.

Yield-Storage Relationships. The relationships between yield and storage were derived by the methods described in Chapter 3. Storage routings were made for each series of historic and generated streamflow, using percentages of average flow as demand, and assuming varying amounts of storage in order to determine the shortage index value previously described. This was done for each station listed in Table C-80. Table C-84 summarizes results in Sub-region F, giving a comparision between synthetic and historic storage requirements for selected demand rates. An example of the results, in graphic format, is shown

KEY STREAMFLOW STATIONS
SUB-REGION F

Analysis Group	NAR Number	Station	Drainage Area (Sq. Mi.)	Approx. Yrs. of Observed Record
I	601	James R. at Lick Run, Va.	1,369	43
I	602	James R. at Buchanan, Va.	2,084	68
I	603	James R. at Holcombs Rock, Va.	3,250	41
I	604	James R. at Scottsville, Va.	4,571	43
I,II	605	James R. at Cartersville, Va.	6,242	69
I	656	James R. nr Richmond, Va.	6,757	32
I	607	Appomattox R. nr Petersburg, Va.	1,335	41
I	608	Chickahominy R. nr Providence Forge, Va.	249	25
II	609	South Anna R. nr Ashland, Va.	393	37
II	610	North Anna R. nr Doswell, Va.	439	41
II	611	Mattaponi R. nr Beulahville, Va.	619	26
II	612	Rappahannock R. nr Fredericksburg, Va.	1,599	59
III	663	North Br. Potomac R. nr Cumberland, Md.	875	37
III	614	So.Br. Potomac R. nr Petersburg, W.Va.	642	38
III	615	So. Br. Potomac R. nr Springfield, W.Va.	1,471	43
III	616	Cacapon R. nr Great Cacapon, W.Va.	677	43
III,IV	667	Potomac R. at Hancock, Md.	4,073	34
III	618	Conococheaque Cr. at Fairview, Md.	494	38
IV	619	So. Fork Shenandoah R. nr Lynwood, Va.	1,076	36
IV	620	So. Fork Shenandoah R. at Front Royal, Va.	1,638	44
IV	621	North Fork Shenandoah R. nr. Strasburg, Va.	772	42
II,III,IV	622	Shenandoah R. at Milville, W.Va.	3,040	52
III,IV	623	Potomac R. at Point of Rocks, Md.	9,651	72
III,IV	624	Monocacy R. at Jug Bridge nr Frederick, Md.	817	38
IV	675	Potomac R nr Washington D.C.	11,560	37

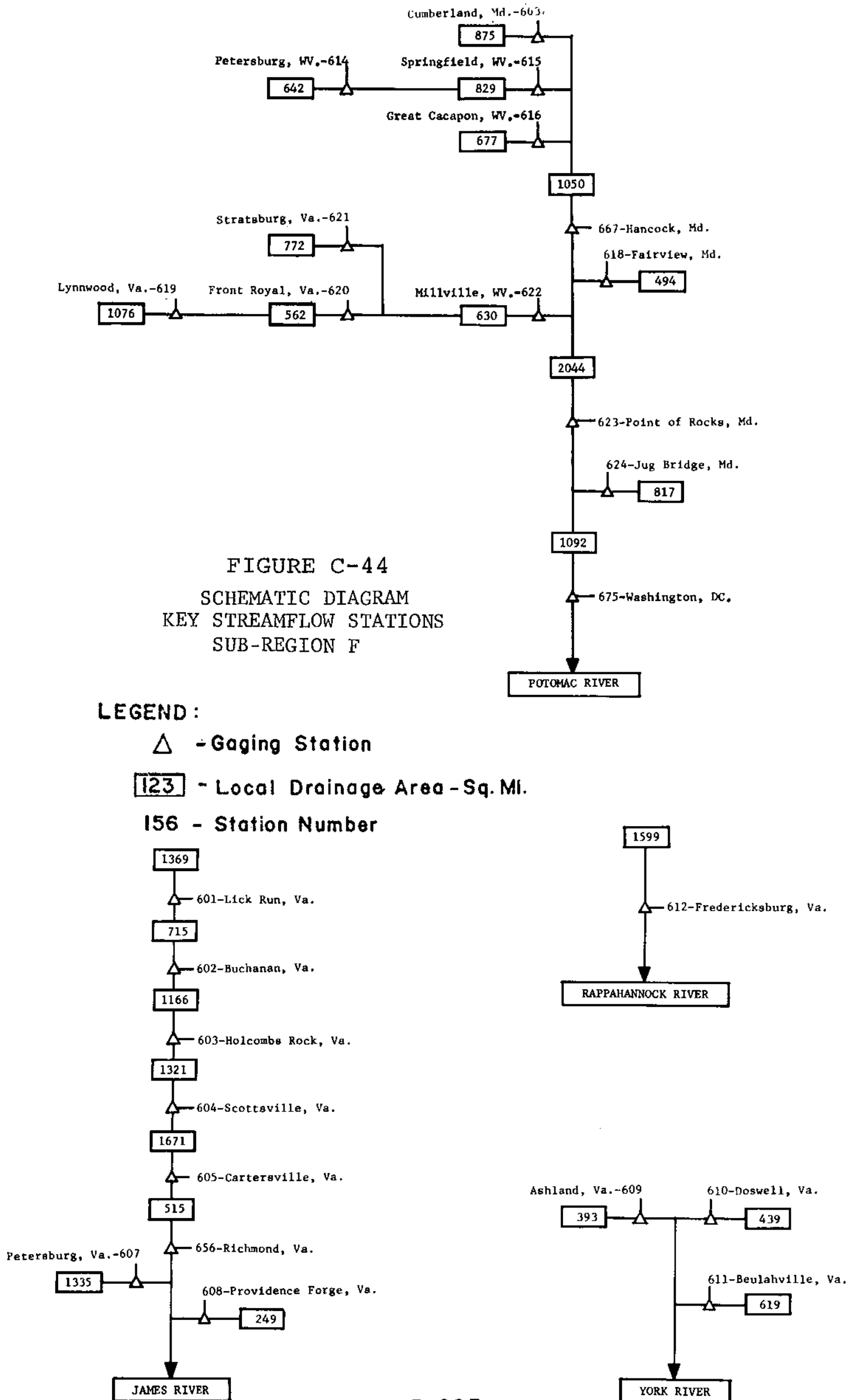


FIGURE C-44

SCHEMATIC DIAGRAM
KEY STREAMFLOW STATIONS
SUB-REGION F

TABLE C-83
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION F
(Cubic feet per second)

Sta. No.		1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
	Hist.	16,043	388	53,549	3,079	264,996	142,351
603	Gen. High	47,601	294	90,372	4,575	337,415	146,294
	Gen. Low	18,679	161	65,813	2,886	270,967	117,830
	Hist.	21,057	499	75,112	4,260	393,102	188,354
604	Gen. High	75,703	490	152,489	6,862	492,164	208,696
	Gen. Low	27,791	280	88,351	4,524	378,166	172,025
	Hist.	8,393	153	23,512	1,288	119,194	61,983
601	Gen. High	12,918	130	36,811	1,661	150,254	65,127
	Gen. Low	8,643	70	29,049	1,039	120,658	51,649
	Hist.	11,459	243	35,292	2,007	181,008	94,305
602	Gen. High	19,361	186	54,097	2,885	221,412	96,778
	Gen. Low	12,655	85	43,844	1,624	184,419	76,846
	Hist.	28,608	528	98,971	4,974	524,953	235,881
605	Gen. High	79,426	539	173,415	9,047	617,972	281,434
	Gen. Low	37,271	308	113,615	5,676	512,019	228,423
	Hist.	29,171	556	105,156	5,186	552,552	249,427
656	Gen. High	113,570	614	204,396	10,105	646,720	301,914
	Gen. Low	36,523	356	127,181	6,480	516,414	249,466

TABLE C-83 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION F

Sta. No.			1 Month		6 Months		54 Months	
			Max.	Min.	Max.	Min.	Max.	Min.
		Hist.	6,803	32	17,755	802	90,037	38,386
607	Gen.	High	10,092	49	29,565	1,491	101,618	47,447
		Low	6,241	18	20,867	846	87,722	37,898
		Hist.	1,445	6	4,416	126	21,769	7,894
608	Gen.	High	3,895	6	10,046	215	27,878	9,960
		Low	1,429	1	4,586	80	20,910	7,091
		Hist.	2,427	6	6,572	183	27,359	12,013
609	Gen.	High	5,153	9	10,096	378	31,841	13,804
		Low	1,841	4	6,197	199	25,636	11,449
		Hist.	2,220	5	6,772	158	31,392	12,963
610	Gen.	High	4,468	12	10,893	412	35,148	14,587
		Low	2,261	3	7,241	230	28,577	12,208
		Hist.	2,903	5	9,074	246	42,872	18,480
611	Gen.	High	5,649	16	14,595	536	50,660	22,895
		Low	2,968	0	9,247	329	42,085	18,332
		Hist.	11,089	15	29,359	382	129,194	55,823
612	Gen.	High	20,496	50	40,041	1,499	154,601	61,436
		Low	10,237	0	29,889	670	116,193	52,347
		Hist.	17,539	302	46,429	2,523	208,969	92,136
622	Gen.	High	108,019	303	167,235	3,147	307,762	98,691
		Low	19,068	194	46,164	2,320	197,174	76,004

TABLE C-83 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION F

Sta. No.			1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
		Hist.	8,759	17	24,573	334	95,810	50,280
663	Gen.	High	20,072	26	45,884	749	117,210	45,296
		Low	9,459	10	26,441	340	92,303	39,916
		Hist.	4,090	48	11,634	388	51,061	28,471
614	Gen.	High	18,554	48	31,328	728	66,335	25,766
		Low	4,107	15	12,266	354	52,936	21,223
		Hist.	10,489	73	22,456	604	93,563	50,951
615	Gen.	High	44,426	59	71,311	1,050	134,589	45,621
		Low	9,452	28	25,294	509	97,524	36,062
		Hist.	5,708	35	13,182	330	46,366	21,941
616	Gen.	High	12,993	29	25,374	366	55,562	19,898
		Low	4,644	17	11,166	227	45,636	14,870
		Hist.	32,278	176	71,274	1,639	290,799	151,584
667	Gen.	High	172,322	180	248,840	2,682	440,716	134,177
		Low	27,968	113	76,527	1,428	293,966	114,137
		Hist.	3,557	42	9,364	332	43,881	19,644
618	Gen.	High	8,513	45	16,769	518	50,910	20,863
		Low	3,551	17	11,305	310	42,261	16,640

TABLE C-83 CONT.
MAXIMUM AND MINIMUM VOLUMES
HISTORIC AND GENERATED STREAMFLOWS
SUB-REGION F

Sta. No.			1 Month Max.	1 Month Min.	6 Months Max.	6 Months Min.	54 Months Max.	54 Months Min.
		Hist.	5,633	36	15,105	603	68,623	30,268
624	Gen.	High	9,058	36	34,351	738	85,644	32,985
		Low	5,085	17	17,229	391	67,755	25,866
		Hist.	68,355	706	157,342	5,671	657,241	350,652
623	Gen.	High	249,199	697	427,025	8,861	880,473	330,053
		Low	56,772	494	163,720	4,792	670,019	277,087
		Hist.	5,842	97	19,309	1,025	86,356	35,240
619	Gen.	High	82,984	108	96,485	1,237	163,589	36,893
		Low	6,282	57	17,739	743	80,233	31,187
		Hist.	10,300	255	31,429	1,735	138,395	54,857
620	Gen.	High	71,970	194	90,263	1,963	194,469	56,742
		Low	11,162	113	28,431	1,337	124,789	48,202
		Hist.	5,017	58	11,219	451	45,932	20,282
621	Gen.	High	10,898	52	18,921	608	57,172	21,675
		Low	3,775	29	9,840	342	43,878	16,546
		Hist.	17,540	343	46,432	2,523	208,981	91,297
622	Gen.	High	111,653	308	142,416	3,065	318,167	95,394
		Low	16,737	173	48,141	1,955	192,814	78,975

TABLE C-84

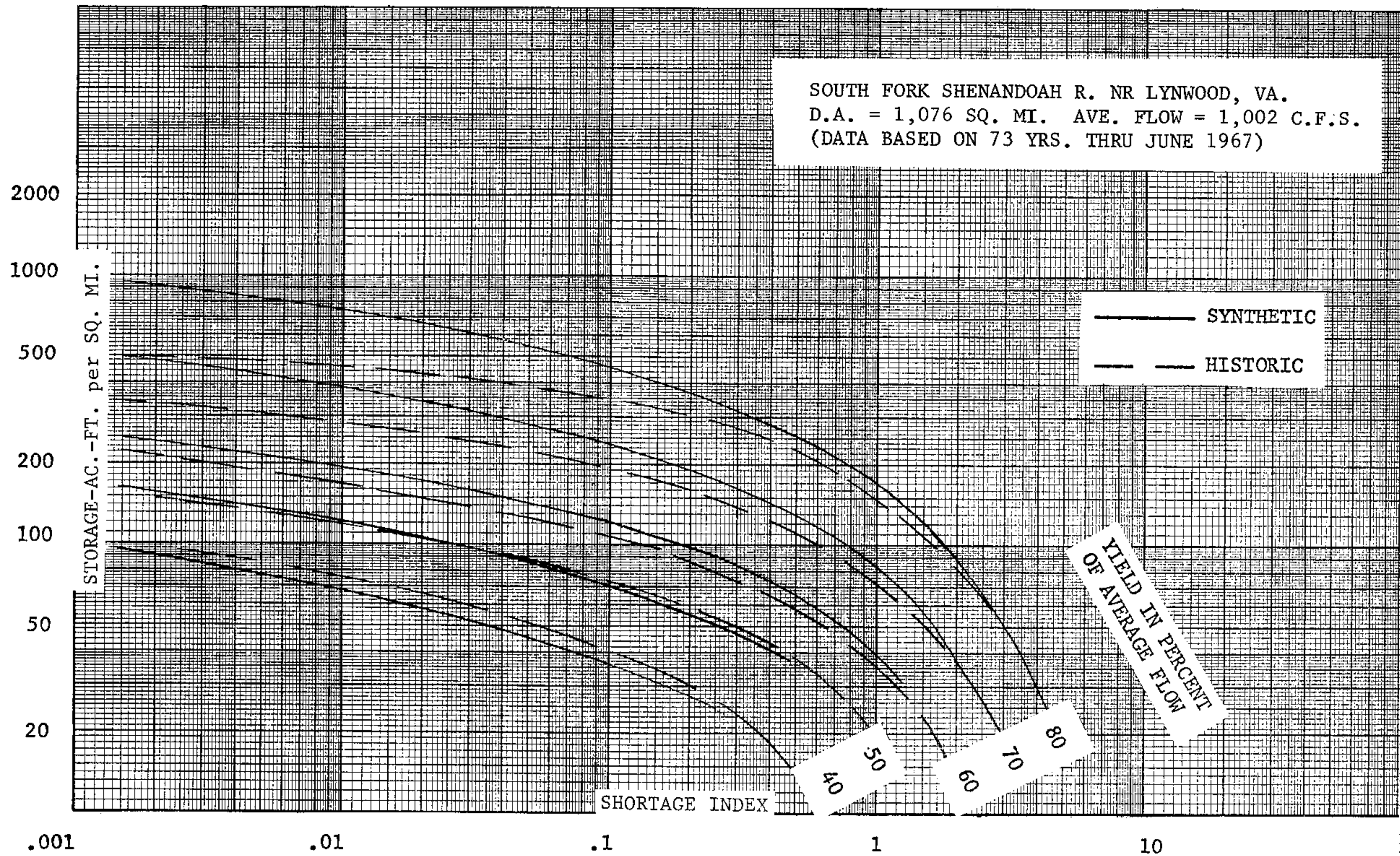
STORAGE REQUIREMENT IN AF/SQ. MI. FOR INDICATED PERCENTAGES OF AVERAGE FLOW

SUBREGION F.

Station	D.A. SQ.MI.	AVERAGE FLOW.CFS.	S.I. = 0.0 HISTORIC 20%	40%	60%	80%	S.I. = 0.01 H 20%	S 20%	H 40%	S 40%	H 60%	S 60%	H 80%	S 80%	S.I. = 0.10 SYNTHETIC 20%	40%	60%	80%
N. Branch Potomac R. @ Cumberland	875	1276	85	215	370	695	68	58	180	165	330	330	600	820	35	120	250	620
S. Branch Potomac R. @ Petersburg	642	712	–	145	265	520	–	–	120	100	225	240	460	800	–	68	170	510
S. Branch Potomac R. @ Springfield, Lcl.	829	596	37	110	240	410	29	29	87	110	195	300	390	910	18	74	200	600
Cacapon R. nr. Great Cacapon	677	570	–	135	250	480	–	–	105	120	205	310	420	800	–	80	210	630
Potomac R. @ Hancock,Lcl.	1050	836	65	195	470	970	54	41	165	130	400	390	820	860	29	95	260	580
Conococheague Ck. @ Fairview	494	568	47	165	300	620	30	22	120	120	260	280	580	850	10	75	200	570
S. Fork Shenandoah R. nr. Lynwood	1076	1002	–	105	250	500	–	–	76	68	165	190	465	740	–	36	120	460
S. Fork Shenandoah R. Front Royal,Lcl.	562	564	–	95	300	580	–	–	64	55	260	220	520	840	–	24	115	525
W. Fork Shenandoah R. nr. Strasburg	772	575	–	105	280	480	–	–	78	66	250	215	420	700	–	36	130	440
Shenandoah R. abv. Mill-ville,Lcl.	630	442	36	96	250	485	29	29	80	86	215	200	440	700	17	53	130	460
Potomac R. abv. Pt. of Rocks,Lcl.	2044	2012	–	165	530	1150	–	–	135	130	380	290	1000	700	–	83	180	490
Potomac R. abv. Pt. of Rocks	9651	9150	34	130	250	500	22	24	100	80	200	220	430	700	10	50	140	440
Monocacy R. abv. Jug. Bridge	817	924	42	180	460	840	30	28	140	120	420	330	740	880	13	75	205	620
Potomac R. abv. Wash. D.C.,Lcl.	1092	1212	–	135	310	740	–	–	105	125	270	315	680	1050	–	78	210	660
S. Anna R. nr. Ashland	393	368	41	130	345	640	30	30	100	100	300	265	580	680	–	58	160	440
N. Anna R. nr. Doswell	439	396	45	140	350	600	33	33	110	95	320	375	575	680	18	52	230	440
Mattaponi R. nr. Beulahville	619	588	46	125	310	670	37	37	110	88	280	250	640	590		55	155	410
Rappahannock R. nr. Fredericksburg	1599	1664	67	255	505	815	50	–	230	120	480	275	765	830	–	68	270	580
James R. abv. Lick Run	1369	1618	30	140	280	560	20	21	100	98	240	250	490	660	–	68	180	440
James R. @ Buchanan,Lcl.	715	842	29	150	315	860	24	32	120	105	260	270	750	820	–	70	190	550
James R. @ Holcombs Rock,Lcl.	1166	1234	24	105	260	550	18	–	76	76	215	215	490	630	–	46	145	410
James R. @ Scottsville,Lcl.	1321	1566	38	125	330	1050	–	–	94	85	275	290	1000	900	–	52	190	550
James R. @ Cartersville, Lcl.	1671	1720	–	155	350	1050	–	–	130	86	300	200	1000	500	–	54	140	300
James R. @ Cartersville	6242	6974	35	145	300	690	22	20	105	78	250	200	650	610	–	42	130	380
James R. @ Richmond,Lcl.	515	532	77	190	440	1100	67	–	170	110	390	280	1050	800	–	72	170	600
Appomattox R. abv. Petersburg	1335	1224	33	120	235	740	23	–	90	70	190	165	680	520	–	46	115	370
Chickahominy R. nr. Providence Forge	249	264	50	155	370	1050	39	39	130	125	340	290	950	1000	24	84	200	660

H = Historic record   S.I. = Shortage Index
S = Synthetic record   Lcl = local area above station

FIGURE C-45. SAMPLE YIELD-STORAGE CURVES - SUB-REGION F



on Figure C-45, for the South Fork Shenandoah River near Lynwood, Va. Using the storages on a per square mile basis, determinations of storages for a given demand rate and a desired shortage tolerance can be made for nearby ungaged locations, using caution not to use drainage areas which are too different from the area for which the curves were constructed.

Minimum Flow. For the purposes of plan formulation, Sub-region F was divided into three Areas: Area 19, which is divided into three Sub-areas; Area 20, with two Sub-areas; and Area 21, which has three Sub-areas.

The existing minimum flow in each Sub-area was derived by computing the monthly flow value from the historic record for a shortage index of 0.01. An adjustment, based on the ratio of the mean seven-day flow during the dry season to the mean minimum monthly flow, was applied to obtain the seven-day low flows for each Sub-area. See Chapter 3 for a description of this methodology.

Where a gaging station did not coincide with a Sub-area outlet, nearby gaging stations were used to estimate the low flow for the Sub-area concerned. Where recorded streamflows did not reflect available resource because of significant reservoir development with diversion from stream channels (within an area), reservoir yields were determined separately and included with the minimum streamflow from uncontrolled areas. Minimum flows do not include yield of reservoirs used for interbasin diversion. Table C-85 lists the minimum flows derived for the Sub-areas in Sub-region F. As described in Chapter 3, adopted seven-day minimum flows are considered to have recurrence intervals of approximately 50 years (Shortage Index 0.01).

As described in the Sub-region E Summary, the interbasin diversion into Area 19 from Area 18 was assumed to be 40 m.g.d. for existing conditions. The existing deversion from the Chowan Basin into Area 21 was assumed to be about half of the transfer capacity, or 25 m.g.d.

Minimum flow and diversion data have been used in studies of existing and practical development resource covered in Appendix E and in connection with NAR Supply Model analyses.

TABLE C-85
EXISTING MINIMUM STREAMFLOW - SUB-REGION F 1/
(Cubic feet per second)

	MONTHLY	7-DAY
Sub-area 19a	335	240
Sub-area 19b	465	230
Sub-area 19c 2/	920	565
AREA 19	1,720	1,035
Sub-area 20a	85	40
Sub-area 20b	115	60
AREA 20	200	100
Sub-area 21a	690	390 (570)
Sub-area 21b 3/	490	185
Sub-area 21c 3/	185	170
AREA 21	1,365	745 (925)
SUB-REGION F	3,285	1,880 (2,060)

1/ Flows in parentheses include allowance for Gathright Lake.
2/ Does not include import from Area 18.
3/ Does not include import from Chowan River Basin.